City and County of Honolulu
Department of Transportation Services
Rapid Transit Division (RTD)

COMPENDIUM OF DESIGN CRITERIA

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HONOLULU HIGH CAPACITY TRANSIT CORRIDOR PROJECT

(PROJECT)

COMPENDIUM OF DESIGN CRITERIA

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Honolulu High-Capacity Transit Corridor Project

(Project)

DESIGN CRITERIA

CHAPTER 3

ENVIRONMENTAL CONSIDERATIONS

May 22, 2009

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3.0 ENVIRONMENTAL

3.1 GENERAL

3.1.1 Introduction

This Chapter establishes the environmental design criteria for the Honolulu High-Capacity Transit Corridor Project (Project).

3.1.2 Goals

The Project shall be designed such that it can be constructed and operated in the environmental conditions of the City and County of Honolulu (City). This Chapter establishes design criteria which are intended to minimize the level of adverse effects to the environment resulting from implementation of the Project.

3.1.3 Reference Data

The Project shall comply with all Local, State, and Federal codes and ordinances governing implementation of a major transit infrastructure project, such as those from, but not limited to, the State of Hawaii Environmental Management Division, the City and County of Honolulu Environmental Services Department, the Federal Environmental Protection Agency, the U.S. Department of Transportation and the Federal Transit Administration regulations. The Project is completing the National Environmental Policy Act process and specifically preparation of an Environmental Impact Statement (EIS). The EIS and Record of Decision describe mitigation measures that will be committed to as part of the implementation of the Project.

Where the requirements stipulated in this document and any referenced source is in conflict, the stricter requirement shall govern.

Unless specifically noted otherwise herein, the latest edition of the code, ordinance, regulation, and standard that is applicable at the time the design is initiated shall be used. If a new edition or amendment to a code, regulation, or standard is issued before the design is completed, the design shall conform to the new requirements to the extent practical or required by the governmental agency enforcing the code, ordinance, regulation, or standard changed.

These criteria are interrelated to the other Chapters of the Compendium of Design Criteria. They should be used collectively to meet the requirements of specifications and design guidelines in accordance with the current practices of the State of Hawaii and the City and County of Honolulu.

3.2 ENVIRONMENTAL CONDITIONS IN THE CITY AND COUNTY OF HONOLULU

3.2.1 General

This subsection summarizes the local environmental conditions and the criteria to be used for the Project. Subsequent subsections specify the criteria in greater detail.

3.2.2 Climate

A. General

The greater Honolulu area climate is considered to be high in temperature and humidity and is in a high wind area.

B. Ambient Temperature

1. Highest recorded: 94°F
2. Yearly average: 77°F
3. Lowest recorded: 52°F

Electrical systems shall be designed for rated operation at 96°F ambient temperature and for normal operation within the ambient conditions in which the equipment is located, including failure of the mechanical ventilation or other temperature control equipment.

C. Relative Humidity

55 percent to 80 percent (average)

D. Precipitation

1. Design for protection against rainfall shall be based on 22 inches annual average rainfall with a rate of 3 inches per hour.
2. Equipment or components exposed to the weather shall be designed for or protected against:
   a. Falling rain
   b. Direct condensation
   c. Flooding
   d. Premature oxidation or deterioration of enclosures or components.

   Coatings selected by the Designer, whenever practical, shall be those with a proven service record in the immediate Honolulu Metropolitan Area.

E. Isoceraunic Conditions

1. Design shall address lightning protection of buildings or structures, since the Project lies within a 7-thunderstorm-days-per-year isoceraunic zone. Refer to NFPA 780 for proper protection.
2. Open power supply lines and high voltage underground cables shall be identified by the Designer and provided with properly coordinated lightning arresters.

3.2.3 Wind Velocity

Information related to wind speed can be found in Chapter 9, Structural.

3.2.4 Elevation

Equipment must be designed and capable of operating without degradation of performance at elevations in the range of sea level (datum) to plus 400 feet.

3.2.5 Geology—Soil

Pertinent soil data are specified in the Geotechnical Data Report prepared for the Project. Additional information issues related to geotechnical engineering can be found in Chapter 9, Structural.

3.2.6 Air Quality

Facilities, equipment, and components shall be capable of operating without detriment under ambient conditions up to maximum recorded levels of pollutants. Refer to the regulations for the control of atmospheric pollution published by the State of Hawaii Environmental Management Division and City and County of Honolulu Environmental Services Department.

3.3 HAZARDOUS MATERIALS

Handling and disposal of hazardous materials shall be in accordance with governmental regulations and shall depend on the hazardous or toxic nature of the material as specified in the EIS on a case-by-case basis.

3.4 LAND ACQUISITION AND DISPLACEMENTS

The Designer will comply with the property requirements for the Project based on what has been documented in the EIS and record of Decision (ROD).

3.5 LAND USE AND ZONING

The Designer will not have any activities relative to assessing impacts in this category.

3.6 FLOODPLAINS, HYDROLOGY, WATER QUALITY

3.6.1 Siltation and Runoff

Catch basins, curbing, culverts, gutters, pumping stations, and storm sewers shall be designed and constructed, as necessary, for the permanent control of water runoff during the operation phase of the Project in accordance with the appropriate governmental regulations. Control of sediments, runoff discharge, and dewatering drainage discharge, including turbidity and pH, shall be as defined by the Designer.

For additional information and requirements, refer to Chapter 6, Civil, and to the regulations for the control of water runoff published by the State of Hawaii Environmental Quality Board.

3.6.2 Water Contamination

A complete Stormwater Management Plan and Report addressing stormwater runoff and water quality will be prepared and submitted by the Designer to the respective agency having jurisdiction prior to construction. A Stormwater Management Plan in conformance with Local and State requirements will be prepared by the Designer for each station and park-and-ride facility.

The Designer shall lay out the yard and shops in order to minimize storm runoff from the operations areas. Runoff from inspection facilities located outside and not covered by a roof or shelter will require the design of collection and pre-treatment facilities prior to discharge to existing water courses.

Washing and service areas shall drain into a collection system where all effluents shall be treated before appropriate disposal. A separating system shall be used to remove unwanted or harmful substances from discharged water. The removed substances shall be disposed of in accordance with the regulations of the State and applicable Local requirements.

Potential for groundwater contamination and adverse effects on groundwater shall be investigated by the Designer for the maintenance and storage facility. The Designer shall avoid surface runoff discharges to groundwater.

3.7 WETLANDS

Any wetlands within the project area shall be delineated in accordance with State and Local standards. The wetlands classification will be obtained through a letter of interpretation application which also serves to verify the delineated wetland boundaries.

If required, wetland mitigation will be identified by the Designer as part of the Project in accordance with Local, State, and Federal regulations. Any wetlands within the project limits will be delineated by the RTD and/or their representative.

3.8 NAVIGABLE WATERS AND COASTAL ZONES

The Project does not interface with any navigable waters. The Designer shall verify any permit requirements associated with crossing the non-navigable waters.

The Project's consistency with the State Costal Zone Management (CZM) Program will be filed by RTD with the Hawaii Department of Business, Economic Development, and Tourism.

3.9 ECOLOGICALLY SENSITIVE AREAS

For ecologically sensitive areas that are identified in the project area and require protection, the Designer will have to propose mitigation consistent with the project goals.

A. A State Incidental Take License for Ko‘oloa‘ula was issued on March 18, 2005, to the State of Hawaii Department of Transportation. The Department of Land and Natural Resources, Division of Forestry and Wildlife (DLNR-DOFAW) will require a Certificate of Inclusion from the State.

B. Clearing and grubbing will be kept to a minimum to mitigate impacts to vegetation.

C. Prior to clearing and grubbing near Koʻoloaʻula contingency reserve, the area will be surveyed. DLNR permitting requirements will be met. If Koʻoloaʻula is found, an arborist from DLNR will be contacted.

3.9.1 Vegetation and Landscaping

As a result of implementing the Project, it will be necessary to remove some existing vegetation, including trees. In order to mitigate these losses, the following criteria will apply.

A. Where existing vegetation and street trees will be removed, new vegetation and trees will be planted where possible and appropriate. Existing street trees will be transplanted where possible or replaced by a new tree. Trees to be transplanted will be selected based on project-specific criteria that will include the following:

1. Areas where existing landscaping would be lost along the study corridor
2. Areas where opportunities exist for enhancing existing streetscapes near the study corridor
3. Areas where stations and parking lots would be constructed
4. Areas where shared benefits would be accomplished, such as areas adjacent to parks or historic sites

B. Street tree pruning, removal, and planting will comply with City ordinances and will require that a certified arborist manage the pruning of any trees.

Refer to Chapter 11, Landscape Architecture, for preparation of such plans.

3.10 ENDANGERED AND THREATENED SPECIES

The Designer will work with State and US Fish and Wildlife Service representatives to mitigate the possible impact on any endangered and threatened species identified in the project area.

3.11 TRAFFIC AND TRANSPORTATION

In some areas, the Project may impact local street capacities. To partially alleviate this, a number of measures will be implemented by the Designer as part of the Project, including revised traffic signalization, the provision of alternative circulation to feed such facilities, and the reconfiguration of certain intersections, widening existing roads, providing left turn lanes, and other treatments.

Also, in areas around stations, increases in local congestion could result. Bus service will be redeployed to provide feeder service to stations. Additional or revised traffic signals will be implemented by the Designer, as determined necessary in consultation with the responsible agency.

During preliminary engineering, the Designer will be asked to utilize available data for traffic volumes (average daily and peak hours) for streets impacted by the Project. Characteristics, levels-of-service, and capacities will also have to be developed for future traffic conditions. The Designer shall account for future traffic conditions, within reason and in close consultation with the affected jurisdiction.

The actual number of parking spaces (on-street and off-street) reduced will be verified by the Designer. Mitigation of any loss of parking will be developed by the Designer and will include parking surveys for affected areas. Mitigation of the lost spaces should be developed by the Designer and coordinated with the appropriate stakeholders, where possible. The Designer will consider adding off-street capacity to replace lost parking.

3.12 ENERGY REQUIREMENTS AND POTENTIAL CONSERVATION

In order to reduce energy consumption, energy conservation features and operating procedures shall be developed for operating systems and subsystems. Such features and procedures shall be examined by the Designer and, if found practical and cost effective, made part of the normal operations of the system.

3.13 HISTORIC PROPERTIES AND PARKLANDS

The Designer shall address any mitigation measures pertaining to the disposition of the State Historic Preservation Division (SHPD) in compliance with Section 106 of the National Historic Preservation Act and/or Section 4(f) or Section 6(f) of the Department of Transportation Act of 1966. Implementation of mitigation measures will be in compliance with the Memorandum of Agreement (MOA) between SHPD and the City and County of Honolulu Department of Transportation Services Rapid Transit Division.

3.14 CONSTRUCTION

The Designer will comply with construction mitigation measures documented in the EIS as part of the design effort. Representative mitigation measures shall address:

A. Noise

B. Disruption of utilities

C. Disposal of debris and spoil

D. Water quality and runoff

E. Access and disruption of traffic

F. Air quality and dust control

G. Safety and security

H. Disruption of business

The Designer will include in the contract documents those provisions necessary to result in the Project conforming to the construction mitigation contained in the Final EIS.

3.15 AESTHETICS/VISUAL

Aerial guideway sections may result in visual incompatibilities in certain areas. As part of the design activities, guideway materials and surface textures shall be selected in accordance with generally accepted architectural principles to achieve an effective integration between the guideway and its surrounding environment. Landscaping and streetscape improvements shall serve to mitigate potential visual impacts.

Stations and park-and-ride facilities shall be designed in a manner which is compatible with the environs. Area and guideway lighting fixtures and standards shall incorporate directional shielding where needed to avoid the intrusion of unwanted light and glare into adjacent sensitive land uses.

With specific regard to the visual treatment of traction power substations (TPSS), the following criteria shall apply:

A. Landscaping shall be used to screen the TPSS from sensitive adjacent land uses, such as residential areas. Lighting and security equipment shall be located so as not to be visible from adjacent sensitive land uses. Local ordinances for screening, signage, and materials shall be followed. Where possible, every effort should be made to integrate a TPSS into a larger structure in the central business districts.

B. Where there is an opportunity to enhance the visual environment with signage, materials, street furniture, landscaping, etc., it should be considered in the design.

Refer to Chapter 9, Structural, Chapter 10, Architecture, and Chapter 11, Landscape Architecture, for additional information. Also refer to Design Language Pattern Book and the Visual and Aesthetic Resources Technical Report.

3.16 SAFETY AND SECURITY

Implementation of the Project carries with it the potential for crimes against persons and property, extending to vehicles, stations, parking areas, and other public areas created by the system. In order to minimize this potential, all system public areas shall be designed to promote maximum safety and security for all system patrons.

Specific design measures which shall be employed are discussed in Chapter 25, System Safety and Security.

3.17 NOISE AND VIBRATION

3.17.1 General Information

This subsection is intended to provide design criteria for noise and vibration control problems relating to the construction and operation of the Project system. The basic goals of these design criteria are to:

A. Adhere to EIS mitigation measures

B. Provide transit system patrons with an acoustically comfortable environment by maintaining within acceptable limits noise and vibration levels in transit vehicles along the way and in stations

C. Minimize the adverse impact of system construction and operation on the community by controlling transmission of noise and vibration to adjacent properties

D. Provide reasonable and feasible noise and vibration control consistent with economic constraints

Design of a rail transit system requires control of airborne noise from transit train operations, transit ancillary areas, and facilities, such as yard operations, electrical substations, and emergency service buildings. The design should also provide for any required control of ground-borne noise and vibration from the transit vehicle operations.

Community acceptance of construction noise and vibration requires that the Designer specify adequate noise control measures and use machinery and equipment with efficient noise and vibration suppression devices and that other noise and vibration abatement measures be employed for protection of both employees and the public.

Providing a satisfactory and comfortable acoustical environment for patrons in enclosed or partially enclosed station areas requires use of sound absorption materials under platform areas, platform level walls and ceilings, and the ceilings and walls of concourse areas for control of mass-transit-originated noise and reverberation in the station. Overall control of station noise also requires inclusion of maximum noise limits in equipment specifications.

The criteria presented in this document are based on those used in the EIS, as derived from the American National Standards Institute, State of Hawaii and City Noise Pollution Regulations, and Federal Transit Administration (FTA) *Guidance Manual for Transit Noise and Vibration Impact Assessment.* Supplemental criteria are adopted from the American Public Transit Association publication, *Guidelines for Design of Rapid Transit Facilities,* and based on experience gained since these guidelines were first published in 1979.

The limits are based on the noise and vibration criteria established in the FTA guidelines in Transit Noise and Vibration Impact Assessment, May 2006, and from State and Local noise regulations. Where these noise and vibration criteria do not set a limit, then limits are used that have been found acceptable in previous rail projects. Whenever projections of noise and vibration indicate that the goals established in this document will be exceeded, special noise and vibration control measures shall be implemented to meet the Project environmental commitments, FTA guidelines, or Local regulations.

3.17.2 Criteria for Wayside Noise

A. Wheel Squeal

Sections of track with tight curves may potentially create a nuisance noise condition referred to as wheel squeal. The sliding or rubbing of the steel wheels of the light metro transit cars across the head of the steel rail causes wheel squeal. Wheel squeal may occur along tight curves in the track with radii of less than 400 feet. Other factors that may affect the potential for wheel squeal include: speed of the train, rail vehicle truck geometry and rigidity, the conditions of the wheels and tracks, wheel damping technology, and contact-surface frictional characteristics.

The potential for wheel squeal shall be identified at locations where tight radius curve trackwork is in close proximity to residential or office buildings. Since it is only possible to anticipate, but not to predict, the occurrence of wheel squeal, mitigation measures will be made available as appropriate to treat a potential problem as soon as pre-revenue system operation begins. During pre-revenue testing of train operations, wayside noise levels will be measured as appropriate at the nearest residential building to these tight-radius curve locations. These measurements will be compared to measurements taken along tangent sections of trackwork, at the same operating speed and distance to the track, to determine if the tight-radius curves may be increasing the wayside noise levels. If audible wheel squeal or higher noise levels are present, then either of the following measures, whichever is more appropriate, may be implemented before the start of revenue service.

1. Dry-stick friction modifiers—Apply friction modifiers on the wheel tread or directly on the running surface of the rail.

2. Lubrication—Wayside lubrication applied to the rail gauge face and wheel flange.

3.17.3 Criteria for Ground-Borne Vibration

Ground-borne noise and vibration are exactly the same phenomena, up to the point of perception at the dwelling. Ground-borne vibration describes waves in the ground, which can be measured using vibration pickups mounted on sidewalks, foundations, basement walls, or stakes in the ground and which can be perceived as mechanical motion. Ground-borne noise describes sound generated when the same waves in the ground reach room surfaces in the buildings, causing them to vibrate and radiate sound waves into the room.

3.17.4 Ground-Borne Noise from Train Operations

The FTA ground-borne noise and ground-borne vibration guidelines are to be used to assess potential impacts due to train operations for different categories of land uses and occupied spaces of various types of buildings and rooms.

Ground-borne vibration meeting the FTA design criteria may not be imperceptible in all cases. The criteria are based on minimizing the occurrence of any significant intrusion or annoyance. In most cases, there will be vibration from street traffic, other occupants of a building, or other sources that will create intrusion that is equal to or greater in level than the vibration from the transit trains.

3.17.5 Ancillary Equipment Noise

TPSSs, emergency diesel generators, and other mechanical equipment required for a rail transit system can all be intrusive sources of noise. In some cases, the noise is particularly intrusive because of its tonal character. Operation of this equipment will comply with the State of Hawaii, Department of Health (HDOH) regulations and specifications. The noise limits shall be reduced by 5 decibels (dBA) if the noise has pure tones or contains an audible screech, whine, or hum or contains information content, such as music or public address system announcements.

3.17.6 Yard and Shop Noise

The storage and inspection yards and maintenance shops shall be designed such that the noise level at the property boundary does not exceed the limits of the Honolulu Noise Ordinance for different land use categories. The applicable limit is based on the zoning of the affected property. The Noise Ordinance limits shall be reduced by 5 dBA for any noise, such as wheel squeal, that has an audible screech, whine, or hum or contains information content, such as music or yard intercom announcements.

3.17.7 Construction Noise and Vibration

The Designer shall conduct a construction noise and vibration assessment to identify the potential impacts to residential land uses and other sensitive activities and determine the need for mitigation measures. The Designer's assessment will provide the Contractor with direction on noise and vibration control measures needed to mitigate potential impacts to residents and other sensitive receptors. The Designer will also establish the need for mandatory noise control measures, such as the use of noise barriers around the construction sites. At a minimum, the Contractor will be directed to comply with all applicable local sound control and noise levels rules, as well as regulations set by HDOH. Construction noise from some activities (e.g., pile-driving in certain sections of the alignment) could reach levels set in the State noise regulations for work between 6:00 p.m. and 7:00 a.m. A variance permit will be required for such nighttime work, which will likely be necessary at certain locations and during certain phases of the Project.

Common sources of vibration during construction activities, including jackhammers, pavement breakers, hoe rams, bulldozers, and backhoes, could potentially affect fragile and historic building structures. The Designer will determine and specify vibration threshold criteria to protect these buildings based on their condition. The Contractor will be directed to provide a Vibration Control Plan that demonstrates that impact generating equipment used at the closest distances to sensitive building structures would not exceed the vibration criteria specified.

Pile-driving close to existing utilities could generate vibration levels that could damage the utility. Existing utilities close to proposed pile-driving locations may need to be further evaluated during final design to determine whether mitigation is needed.

3.18 REFERENCES

A. Air Moving and Conditioning Association (AMCA). 1985. Standard 300-85. *Test code for sound rating air moving devices.*

B. American National Standards Institute (ANSI). 1983. S1.4-1983. *Specification for sound level meters.*

C. American Public Transit Association (APTA). January 1979. *Guidelines for design of rapid transit facilities.*

D. City and County of Honolulu. Revised February 1997. *Noise ordinances of Honolulu.*

E. Code of Federal Regulations. 29 CFR Part 1910. *Department of Labor occupational noise exposure standard.*

F. Hawaii Environmental Quality Board. 1987. *Regulation for the control of noise pollution (amended version).*

G. International Electromechanical Commission (IEC). 1973. Publication 179. *Precision sound level meters.*

H. National Fire Protection Association (NFPA). 2007. NFPA 130. *Standard for fixed guideway transit and passenger rail systems.*

I. Society of Automotive Engineers (SAE). 1973. J366b. *Exterior sound level for heavy trucks and buses.*

J. Society of Automotive Engineers (SAE). 1973. J952b. *Sound levels for engine powered equipment.*

K. Society of Automotive Engineers (SAE). 1979. Jag. *Exterior sound level measurement procedure for earthmoving machinery.*

L. U.S. Department of Transportation, Federal Transit Administration (FTA). 1979. Circular C5620.1. *Guidelines for preparing environmental assessments.*

M. U.S. Department of Transportation, Federal Transit Administration (FTA). July 1990. UMTA-DC-08-9091-90-1. *Draft guidance manual for transit noise and vibration impact assessment.*

N. U.S. Department of Transportation, Federal Transit Administration (FTA). May 2006. FTA-VA-90-1003-06. *Transit noise and vibration impact assessment, final report.*

O. U.S. Department of Transportation, Federal Transit Administration (FTA). May 2006. *Guidance manual for transit noise and vibration impact assessment.*

P. Geotechnical Data Report

Q. Regulations for the control of atmospheric pollution State of Hawaii Environmental Management Division and City and County of Honolulu Environmental Services Department

R. Regulations for the control of water runoff published by the State of Hawaii Environmental Quality Board

S. Design Language Pattern Book

T. Visual and Aesthetic Resources Technical Report.

U. State of Hawaii noise regulations.

END OF CHAPTER

HONOLULU HIGH-CAPACITY TRANSIT CORRIDOR PROJECT

(Project)

DESIGN CRITERIA

CHAPTER 4

TRACK ALIGNMENT AND VEHICLE CLEARANCES

April 3, 2009

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4.0 TRACK ALIGNMENT AND VEHICLE CLEARANCES

4.1 GENERAL

The Track Alignment and Vehicle Clearances Criteria has been established to provide for a comfortable, economical, and efficient transport for passengers while maintaining adequate factors of safety with respect to overall operation, maintenance, and vehicle stability. They have been developed by utilizing accepted engineering practices and the experiences of currently operating rail transit and railroad systems.

4.2 RAIL TRANSIT TRACK ALIGNMENT

4.2.1 General

The track alignment shall be designed to accommodate a maximum design speed of 55 miles per hour (mph). Physical constraints along various portions of the system, together with other design limitations, may preclude achievement of this objective. The civil design speed shall be coordinated with the normal operating speeds as provided on the train performance simulation program speed-distance profiles.

Coordination of horizontal and vertical alignment shall avoid a combination of minimum radius, maximum grade, and maximum unbalanced elevation.

For areas of special trackwork, the following table illustrates the prescribed design speeds. Generally, the maximum level of unbalance (E_u) allowed through any area of special trackwork shall be limited to 2 inches. Any deviations from these speeds through special trackwork shall require the review and approval of the City and County of Honolulu Department of Transportations Services the Rapid Transit Division (RTD) on a case-by-case basis. Track alignment design shall consider the placement of all special trackwork while designing areas of horizontal and vertical alignment.

Turnouts and Crossovers	Speed (mph)
No. 6	10
No. 8	15
No. 10	20
No. 15	30

For mainline track, the track centers shall be 14 feet (minimum) through areas of tangent and curve, including side platform locations. Track centers shall be 40 feet (minimum) through center platform locations.

4.2.2 Horizontal Alignment

The horizontal alignment of mainline tracks shall consist of a series of tangents joined to circular curves by means of spiral transition curves. Superelevation shall be used to maximize running speeds whenever practical.

A. Tangent Alignment

The minimum length of tangent track between curved sections of track shall be as follows:

Condition	Tangent Length
Desirable minimum	200 feet
Minimum	100 feet or 3 times the design speed (in mph), whichever is greater
Absolute minimum	70 feet

If adjacent curves in the same direction are in close proximity to one another and cannot be replaced by a single simple curve due to geometric constraints, a series of compound curves shall be the preferred arrangement. Broken back curves (i.e., short tangents between curves in the same direction) shall be avoided.

At station platforms, the horizontal alignment shall be tangent throughout the entire length of the platform. The tangent shall be extended beyond both ends of the platform as follows:

Condition	Tangent Length
Desirable minimum	75 feet
Minimum	60 feet
Absolute minimum	45 feet

All special trackwork shall be located on horizontal tangents. The same limits prescribed above should be used between areas of special trackwork and horizontal/vertical curve limits.

1. Track Centers in Tangent Alignment

Tracks shall be parallel within all sections of tangent track. Track centers shall be 14 feet in tangent sections. Track centers through side platforms shall also be 14 feet. Track centers shall be 40.5 feet within the limits of center platforms.

B. Curved Alignment

Intersections of horizontal tangents shall be connected by circular curves by either simple curves or spiraled curves as required by these criteria.

1. Circular Curves

Circular curves shall be specified by their radius. Degree of curvature (arc definition), where required for calculation purposes, shall be defined by the following formula:

$$D = \frac{5729.58}{R}$$

where: D = degree of curvature
R = radius of curvature, in feet

The minimum radii for mainline tracks shall be as follows:

Location	Minimum Radius
Aerial structures	500 feet
At-grade	300 feet

The minimum radii for yard and service tracks shall be as follows:

Location	Minimum Radius
Yard and service tracks	250 feet desirable
	150 feet absolute

The desirable minimum circular curve length shall be determined by the following formula:

$$L = 3V$$

where: L = minimum length of curve, in feet
V = design speed through the curve, in mph

For spiraled circular curves, the length in feet of the circular curve added to the sum of one-half the length of both spirals shall be an acceptable method of determining compliance with the above criteria.

The absolute minimum length of a superelevated circular curve shall be 70 feet.

The design speed for a given horizontal curve shall be based on its radius, length of spiral transition, and actual and unbalance elevation through the curve as described in the following sections.

2. Track Centers in Curves

Tracks shall be concentric in all curves. Track centers shall not be less than 14 feet through curves and may need to be widened to accommodate the selected vehicle.

3. Superelevation

Mainline tracks shall be designed with superelevation so as to permit desired design speeds to be achieved without resorting to excessively large radii of curvature. Note that due to local constraints, the design speed may be less than either the system maximum speed or the maximum possible speed for a curve of a given radius. The design speed criteria stated herein are based on a maximum lateral acceleration of the passenger of 0.125 g, where g is a measure of apparent gravity caused by acceleration.

Equilibrium elevation is the amount of elevation that would be required so that the resultant force from the center of gravity of the rail vehicle will be perpendicular to the plane of the two rails and halfway in between them at a given speed. If a curved track is superelevated so as to achieve equilibrium at a given speed, a passenger would experience no centrifugal force through the curve at that speed. Equilibrium elevation shall be determined by either of the following equations:

$$E_q = E_a + E_u = 3.96\left(\frac{V^2}{R}\right)$$

or

$$E_q = 0.00069\,V^2\,D$$

where:
- E_q = equilibrium elevation, in inches
- E_a = actual track superelevation to be constructed, in inches
- E_u = unbalance elevation, in inches
- V = design speed through the curve, in mph
- R = radius of curve, in feet
- D = degree of curve, in degrees (arc definition)

In practice, the full equilibrium elevation (E_q) is rarely installed in track as doing so would require excessively long spiral transition curves. It could also produce passenger discomfort on board a train which is moving much slower than the design speed or stopped in the middle of a steeply superelevated curve. Therefore, only a portion of the calculated E_q, the actual superelevation E_a, shall be designed for and installed in the track. The difference between the equilibrium elevation and the actual superelevation is called the unbalance, and is designated as E_u.

The desired relationship between E_a and E_u shall be defined by the following equation:

$$E_u - \left(\frac{E_a}{2}\right) = 1$$

Desirable values of actual superelevation (E_a) can be determined by the following formula:

$$E_a = 2.64\left(\frac{V^2}{R}\right) - 0.66$$

The two equations noted above are guidelines and should not preclude the Designer from using sound engineering judgment in order to determine the optimum level of superelevation (E_a) that can accommodate the highest practical speed, while not imposing excessively long spirals. Use of the above equation will result in the gradual introduction of both actual and unbalanced elevation and avoid unnecessary lateral acceleration of rail vehicles and their passengers. Values for actual superelevation shall be rounded to the nearest one-quarter inch. For a total elevation (E_q) of 1 inch or less, no actual superelevation (E_a) is needed.

Actual superelevation (E_a) shall be attained and removed linearly throughout the full length of the spiral transition curve by raising the outside rail while maintaining the inside rail (or low rail) at the profile grade line.

The maximum values for actual and unbalance elevation shall be as follows:

Elevation	Maximum Value
E_a =	4 inches desirable 6 inches absolute
E_u =	3 inches desirable 4.5 inches absolute

4. Spiral Transitions

Spiral transition curves shall be used in order to develop the superelevation of the track and limit lateral acceleration during the horizontal transition of the rail vehicle as it enters the curve. Spirals shall be Barnett or Talbot as defined by the AREMA Manual for Railway Engineering.

The minimum length of spiral shall be the greater of the lengths determined from the following formulae, but preferably not less than 60 feet:

$$L_s = 62\ E_a$$

$$L_s = 1.22\ E_u\ V$$

$$L_s = 1.10\ E_a\ V$$

where: L_s = minimum length of spiral, in feet.

A spiral is preferred, but not required, for yard and secondary tracks where design speeds are less than 10 mph. Yard and secondary tracks which have design speeds greater than 10 mph shall have spirals, and superelevation is required when at all feasible.

Under normal situations, superelevation shall be introduced and run off uniformly through the length of a spiral transition curve.

Spirals will not be required for curves where the total equilibrium elevation (E_q) is less than or equal to 1 inch and E_a is zero.

5. Compound Circular Curves

Where compound curves are used, they shall be connected by a spiral transition curve. The absolute minimum spiral length shall be the greater of the lengths as determined by the following:

$$L_s = 62\ (E_{a2} - E_{a1})$$

$$L_s = 1.22\ (E_{u2} - E_{u1})\ V$$

$$L_s = 1.10\ (E_{a2} - E_{a1})\ V$$

where: L_s = minimum length of spiral, in feet
E_{a1} = actual superelevation of the first circular curve, in inches
E_{a2} = actual superelevation of the second circular curve, in inches
E_{u1} = unbalanced elevation of the first circular curve, in inches
E_{u2} = unbalanced elevation of the second circular curve, in inches
V = design speed through the circular curves, in mph

Spiral transition curves connecting compound curves are not required when (E_{u2} - E_{u1}) is less than 1 inch and (E_{a2} - E_{a1}) equals zero.

6. Reverse Curves

Where extremely restrictive horizontal geometrics make it impossible to provide sufficient tangent length between reversed superelevated curves, the curves may meet at a point of reverse spiral. These locations must be reviewed on a case-by-case basis and will require the approval of RTD.

The point of reverse spiral shall be set so that:

$$L_{s1} \times E_{a2} = L_{s2} \times E_{a1}$$

where: E_{a1} = actual superelevation applied to the first curve
E_{a2} = actual superelevation of the second circular curve, in inches
L_{s1} = the length of the spiral leaving the first curve
L_{s2} = the length of the spiral entering the second curve

A maximum separation of three feet between the spirals is acceptable in lieu of meeting at a point.

4.2.3 Vertical Alignment

A. General

The vertical alignment shall be composed of constant grade tangent segments connected at their intersection by parabolic curves having a constant rate of change in grade.

The profile grade line in tangent track shall be along the centerline of track between the two running rails and in the plane defined by the top of the two rails. In curved track, the inside rail of the curve shall remain at the profile grade line and superelevation achieved by raising the outer rail above the inner rail.

B. Vertical Tangents

The minimum length of constant profile grade between vertical curves shall be as follows:

Condition	Length
Desirable minimum	100 feet or 3 times the design speed (in mph), whichever is greater
Absolute minimum	70 feet

The profile at stations shall be on a vertical tangent that extends 60 feet beyond each end of the platform. Special trackwork shall be located on vertical tangents.

C. Vertical Grades

The following profile grade limitations shall apply:

Location	Condition	Profile Grade Limitations
Mainline tracks	Maximum (sustained grade unlimited length)	4.0%
	Maximum (sustained grade with up to 2,500 feet between PVI's of vertical curves)	6.0%
Station area	Desirable	0.5%
	Maximum	1.0%
Yard tracks	Desirable	0.0%
	Maximum	1.0%
Yard storage and pocket tracks	Desirable	0.0%
	Maximum	0.2%

All tracks entering the yard shall either be level, sloped downward away from the mainline, or dished to prevent rail vehicles rolling from the yard onto the mainline. For yard secondary tracks, it is desirable to have a slight grade, maximum 1.0 percent and minimum 0.35 percent, to achieve good track drainage at the subballast level.

Through storage tracks shall have a sag in the middle of their profile to prevent rail vehicles from rolling to either end. It is desirable that the profile grade of a stub end storage track descend towards the stub end and, if adjacent to a mainline or secondary track, be curved away from that track at its stub end. If it is necessary for the profile grade of a storage track to slope up toward the stub end, the grade shall not exceed 0.2 percent.

Tracks located within maintenance shop buildings shall be level with a 0 percent grade.

4.2.4 Vertical Curves

All changes in grade shall be connected by vertical curves. Vertical curves shall be defined by parabolic curves having a constant rate of change in grade.

A. Vertical Curve Lengths

The minimum length of vertical curves shall be determined as follows:

Desirable length $LVC = 200A$

Preferred minimum length $LVC = 100A$

Absolute minimum length

Crest curves $$LVC = \frac{AV^2}{25}$$

Sag curves $$LVC = \frac{AV^2}{45}$$

where:
- LVC = length of vertical curve, in feet
- A = $(G_2 - G_1)$ = algebraic difference in gradients connected by the vertical curve, in percent.
- G_1 = percent grade of approaching tangent
- G_2 = percent grade of departing tangent
- V = design speed, in mph.

Both sag and crest vertical curves shall have the maximum possible length, especially if approach and departure tangents are long. Vertical broken back curves and short horizontal curves at sags and crest of vertical curves shall be avoided.

B. Compound Vertical Curves

Compound and unsymmetrical vertical curves shall be permitted on a case-by-case basis and will require the approval of RTD.

C. Reverse Vertical Curves

Reverse vertical curves shall be permitted on a case-by-case basis and will require the approval of RTD.

D. Combined Vertical and Horizontal Curvature

Where possible, areas of combined vertical and horizontal curvature shall be avoided, specifically within spirals. Vertical curves kept within the body of curve (between the spiral-to-curve [SC] and curve-to-spiral [CS] points) will be acceptable. Vertical curves within the limits should be avoided but will be allowed so long as the prescribed superelevation is less than 3 inches.

4.3 VEHICLE CLEARANCES

4.3.1 General

This section establishes the minimum dimensions required for proper clearances between the rail vehicles or transit structures and the obstructions involved. All designs shall meet or exceed the minimum clearance criteria as specified herein. Since the provision of adequate clearances for the safe passage of rail vehicles is one of the most fundamental concerns inherent in the design of the system, it shall be rigorously monitored during both the design and construction phases.

4.3.2 Clearance Envelope

The Clearance Envelope (CE) is defined as the space occupied by the Vehicle Dynamic Envelope (VDE) plus the effects of other wayside factors (OWF), including construction and maintenance tolerances for track and various facilities, plus running clearances (RC). This relationship can be expressed as follows:

$$CE = VDE + OWF + RC$$

The CE represents the space into which no physical part of the system (other than the rail vehicle) shall be placed, constructed, or protrudes. The CE shall be referenced from the centerline of track at the top of rail.

The following factors shall be considered in developing the CE.

A. Vehicle Dynamic Envelope

Determination of the VDE begins with the cross sectional outline of the static vehicle. The dynamic outline of the vehicle is then developed by making allowances for the car body movements that occur when the vehicle is operating on level, tangent track. In addition to car body movements on level, tangent track, the effects of track curvature and superelevation must also be considered to allow additional room for vehicle overhang on curves and for vehicle lean when the curves are superelevated.

1. Static Vehicle Outline

   Design of the project is typically initiated prior to the specific dimensional characteristics of the rail vehicle being known. In order to allow design of fixed facilities to proceed, a composite design vehicle concept has been employed which incorporates the most critical dimensions and operational characteristics of the rail vehicles considered for the project.

2. Dynamic Vehicle Outline

   The dynamic outline of the vehicle shall be defined as the extreme car body displacement that can occur for any combination of rotational, lateral, and vertical car body movements that occur when the vehicle is operating on level, tangent track. These car body movements are due to truck suspension movements, spring action, allowable wheel and rail wear, and permitted tolerances in vehicle and track construction.

3. Vehicle Inswing/Outswing

In addition to the dynamic car body movements described above, car body overhang on horizontal curvature also increases the lateral displacement of dynamic outline relative to the track centerline. For design purposes, both mid-car inswing and end-of-car outswing of the vehicle shall be considered. The amount of mid-car inswing and end-of-car outswing depends primarily on the truck spacing and end overhang of the vehicle and on the radius of track curvature.

4. Superelevation Effects

The effect of superelevation shall also be taken into account in developing the VDE. Superelevation effects shall be limited to the vehicle lean induced by a specified difference in elevation between the two rails of a track and shall be considered independently of other effects on the dynamic outline. In determining the superelevation effects, the shape of the dynamic outline shall not be altered. Rather, the dynamic outline shall be rotated about the centerline of the top of low rail an amount equal to the actual track superelevation.

When calculating the VDE for horizontal curves with spirals, the tangent CE shall end 50 feet before the tangent-to-spiral (TS) and 50 feet beyond the spiral-to-tangent (ST) point. The full curvature CE shall begin 25 feet prior to the SC point and end 25 feet beyond the CS point. The horizontal component of the VDE between these two offset points (i.e., 50 feet before the TS and 25 feet before the SC) shall be considered to vary linearly with distance between the two points. Horizontal offsets at intermediate locations shall be calculated by linear interpolation. For simple circular curves, the full curvature CE shall begin 50 feet prior to the point of curvature (PC) and end 50 feet beyond the point of tangency (PT).

The CE through turnouts shall be calculated based on the centerline radius of the turnout.

B. Other Wayside Factors

The following define the other wayside factors and are applicable to and shall be included in the horizontal component of the CE.

Other Wayside Factors	Distance
Construction tolerance along proposed soldier pile and lagging wall	6 inches
Construction tolerance along all other proposed structures	2 inches
Construction tolerance at poles or signal equipment	1.5 inch
Track construction and maintenance tolerance for embedded or direct fixation track	0.5 inch
Track construction and maintenance tolerance for mainline, ballasted track	2.5 inches
Track construction and maintenance tolerance for secondary and yard tracks	1 inch
Allowance for acoustical treatment, where required	3 inches

C. Running Clearances

In addition to the VDE and other wayside factors, the CE includes an allowance for RC. The following define the running clearances to be included in the horizontal component of the CE.

Running Clearances	Distance
At poles, signals, signs and other non-structural members	2 inches
Along soldier pile and lagging walls and other structures which are normally constructed with liberal construction tolerances	6 inches
Along cast-in-place, precast, and masonry walls and other structures which are normally constructed with strict construction tolerances	2 inches
For adjacent rail vehicles	2 inches

The above dimensions are design values, the applicability of which depends on the type of track construction as well as on the type of structure which the vehicle must clear. The following is a description of the applicability and rationale of these values.

1. Track Construction and Maintenance Tolerances

   The combination of several factors, such as track misalignment and wheel and track gauge tolerances, creates the need for this tolerance. Ballasted track demands a greater track misalignment tolerance than either direct fixation or embedded track would require. Furthermore, a distinction is also made between primary tracks and secondary or yard tracks for safety reasons.

2. Construction Tolerances along Proposed Structures

   Where the facility adjacent to the trackway is a structure or part of a structure, the minimum horizontal construction tolerance shall be provided on the assumption that the structure, or part thereof, may be misplaced during construction by a dimension of that magnitude. It is emphasized that the term "structure" as used in this subsection applies to any facility to be constructed alongside the rail system and above the top of rail.

3. Acoustical Treatment

   The need for this allowance shall be investigated in cases where noise produced from the system operations may be found in excess of tolerable limits for a given area.

4. Running Clearances

   To provide clear passage for a vehicle which has moved to the extreme position within the Dynamic Outline, the minimum horizontal clearance to any structure, or part of a structure, shall always include a horizontal running clearance.

4.3.3 Special Clearance Situations

In addition to the CE requirements described above, there are several special clearance situations warranting further definition. These special situations include the vehicle interface at station platforms, retaining walls in both cut and fill sections, through girder bridges, and maintenance and emergency evacuation paths.

A. Vehicle Interface at Station Platforms

At passenger stations, the distance from the centerline of the track to the edge of platform tolerance shall be plus ½ inch and minus 0 inches.

B. Retaining Walls

Where retaining walls are used, they shall comply with the following:

1. Cut Sections

   In those cases where a retaining wall along the system is in a cut section, the preferred minimum clearance from the centerline of track to the near face of a retaining wall shall be 9 feet 0 inches. Where no maintenance and emergency evacuation path is required adjacent to the retaining wall, the absolute minimum clearance from the centerline of track to the near face of a retaining wall shall be no less than that required to clear the CE and never less than 6 feet 7 inches.

2. Fill Sections

   In retained fill sections, the top of a retaining wall shall be at the same elevation as the top of the adjacent rail (the rail nearest to the wall), and the preferred minimum distance from the centerline of track to any fencing or hand railing on top of the wall shall be a minimum of 9 feet 0 inches. Where no maintenance and emergency evacuation path is required adjacent to a curb or retaining wall without a fence or railing, the absolute minimum clearance from the centerline of track to the near face of the curb or wall shall be no less 6 feet 0 inches.

C. Maintenance and Emergency Evacuation Paths

A minimum clear width of 30 inches (48 inches desirable) shall be provided between the CE and any continuous obstruction alongside the track in a designated passenger emergency evacuation path. A minimum clear distance of 24 inches shall be provided between the CE and any continuous obstruction along a path which is used by maintenance employees in the performance of their duties.

4.3.4 Vertical Clearances to Overhead Structures

The following vertical clearances from the top of the high rail along any given section of track to the soffit of any overhead structure within the horizontal limits of the CE shall be provided:

Location	Minimum Vertical Clearance
At overhead bridges	16 feet 0 inches, preferred minimum
	14 feet 0 inches, desired minimum
	13 feet 0 inches, absolute minimum

END OF CHAPTER

Honolulu High-Capacity Transit Corridor Project

(Project)

DESIGN CRITERIA

CHAPTER 5

TRACKWORK

May 22, 2009

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5.0 TRACKWORK

5.1 GENERAL

5.1.1 Introduction

This Chapter sets forth standards and design policies to govern the detailed engineering, materials, and construction standards for the types of track structure, the trackwork, and its interface with other elements on the Honolulu High-Capacity Transit Corridor Project (Project). Limits of work covered by this Chapter are from the top of trackway, as defined herein, to the top of rail and the necessary interfaces of trackwork with other elements. "Trackwork," as it used in this chapter, refers to the types of track, individual standard track components as ballast, rail, fasteners, etc., and "Special Trackwork" such as turnouts, crossovers, double crossovers, track crossing (diamonds), pre-curved rail, and restraining rail.

All trackwork described herein shall govern the design of track for the guideway structure deck, the aerial and at-grade direct fixation track, the ballasted yard track, the transition slab track, drainage, and the interfacing traction power system and signal system, including the vehicle parameters. Construction Specifications and Trackwork Standard/Directive Drawings shall comply with these criteria.

All trackwork shall be specified to be new materials.

5.1.2 Reference Data

Track design shall be in accordance, as applicable, with the requirements of the following:

A. Transit Cooperative Research Program (TCRP) Report 57—*Track Design Handbook for Light Rail Transit*

B. American Railway Engineering and Maintenance-of-Way Association (AREMA) *Manual for Railway Engineering and Portfolio of Trackwork Plans*

C. TCRP Report 71—*Track Related Research Volume 6: Direct Fixation Track Design Specification, Research, and Related Material*

D. TCRP Research Results Digest 79—*Design of Transition Slabs*

5.1.3 Related System Interface

The various track types noted are composed of a number of elements, each of which has a definite interaction with other elements of the system. Because of this interaction, the design criteria for trackwork must be undertaken as a systems approach with a cause-and-effect analysis being undertaken on each of the elements. In performing this trackwork design, consideration of allied factors, such as safety, ride comfort, stray current, noise, and vibration, must be considered. In addition, the relationship of trackwork design to the design of other elements of the system, such as traction power, signal system, train control, drainage, and type of vehicle, must be recognized and accommodated early in the design process.

For track geometry and track clearances, see Chapter 4, Track Alignment and Vehicle Clearances.

5.2 TRACK CLASSIFICATIONS

Tracks for this Project shall be classified as described below.

5.2.1 Mainline Track

Mainline track shall be for the operation of vehicles carrying revenue passengers and shall consist of a double-track system. Non-revenue tracks within the mainline system, such as staging pocket tracks and sidings, single crossovers, and double crossovers, which are critical to the mainline operation, shall also be classified as mainline track and function under the Operations Control Center (OCC). All access to the mainline track shall commence at the Maintenance and Storage Facility (MSF) site.

5.2.2 Transfer (Ready/Layover) Tracks

Transfer tracks classified as yard tracks and located at the yard site adjacent to the mainline shall be non-revenue track but considered as mainline track and function under the control of the Operations Control Center.

5.2.3 Yard Track

Yard track located at the designated yard site adjacent to the mainline shall be non-revenue track. Yard track shall consist of a storage and daily inspection yard for spotting of cars, a maintenance shop yard providing access and spotting cars to be serviced at the Maintenance Shop Building, a wash and cleaning track, and a maintenance of way yard. Access to the entire track system for highway vehicles equipped with flanged wheels to drive onto the track shall be provided at strategic locations.

5.3 TRACK TYPES

Tracks for this Project shall be designed by track types as described below.

5.3.1 Mainline Ballasted and Direct Fixation Track

Mainline direct fixation track shall be on aerial structure and mainline ballasted track on at-grade sections. The direct fixation plinths shall consist of aerial direct fixation track (and at-grade direct fixation slab track) with standard and special resilient and insulated rail fastener types to mitigate ground- and air-borne wheel/rail generated noise, vibration, and stray current. The direct fixation plinths shall be purposely segmental along the aerial structure to accommodate locations of transverse structural joints, drainage openings, and signal and traction power surface deck cabling. For grounding of reinforcement, refer to Chapter 9, Structural.

The concrete for plinths shall be of a special mix containing silica fume to reduce stray current passage. The reinforcing bar system shall be epoxy-coated, isolated from the main structure deck, (and an at-grade slab) reinforcing bar system.

Mainline ballasted track shall be on at-grade sections. The ballasted track shall consist of ballast and concrete crosstie track.

Mainline track and special trackwork shall be of continuous welded rail (CWR) installation, and longitudinal rail anchor requirements shall be developed considering rail-to-structure interface at special trackwork and other structure locations.

Emergency pedestrian walkways and track crossings shall be required for emergency evacuation. Emergency pedestrian track crossings shall be fully insulated for stray current control.

The mainline and yard track traction electrification systems will have different traction power substation systems and shall require return rail separation. Coordination with the traction power designer is required to position the bonded (glued) insulated rail joints adjacent to the mainline in the yard ballasted track section.

5.3.2 Yard Direct Fixation Track

Yard direct fixation track shall be required at the yard wash track and cleaning facility and shall be of similar design as the mainline, except for single- or double-fastener plinth lengths for the purpose of floor drainage. The concrete plinth design shall be reduced to a pad height configuration.

5.3.3 Ballasted Yard Track

The MSF yard tracks shall be ballasted track with concrete crossties. The yard tracks shall be accessed by minimum No. 6 Turnouts in a ladder track or fan-type track layout. Special trackwork shall be installed on concrete switch-ties. Ballasted yard track and special trackwork shall be CWR installation. Transition track (ballasted to direct fixation track) shall be a requirement within the MSF yard. Access roadways with pedestrian walkways shall be required within the MSF yard. Where practicable, a service road within the yard right-of-way and paralleling the track shall be provided with adequate turn-around facilities where the road is not continuous. The road crossings shall be fully insulated for stray current control. Surface runoff and drainage through the track system and at adjacent roadways is paramount in the initial design. Proper design of the roadbed and ballast elements of the yard track structure shall provide a sound foundation to minimize the long-term maintenance requirements of the transit system. Roadbed and ballast sections shall be designed and analyzed to minimize the overall right-of-way width required while providing a uniform, well-drained foundation for the track structure. Rail support track modulus shall be designed in accordance with the AREMA Manual for Railway Engineering, Chapter 22.

5.3.4 Embedded Shop Track

Embedded shop track shall be located within the maintenance shop floor area and shall include the surrounding exterior building apron extensions around the Maintenance Shop Building where workers and rubber-tired vehicles must share the trackway as a road crossing. The maintenance shop track traction power shall be provided from a different source from the yard traction power substation, and the shop track shall require return rail grounding. The position of the bonded (glued) insulated rail joints adjacent to the building apron areas in the ballasted track section shall be coordinated with Traction Electrification System design. The embedded shop track shall be CWR installation. To provide for the safety of vehicle maintenance personnel, all shop tracks shall not be insulated from ground. It shall be electrically connected to the negative bus of the Maintenance Shop Building traction power supply.

5.3.5 Pedestal Shop Track

Pedestal shop track shall be constructed within the limits of the maintenance building's designated pit track service areas. This can include several configurations with the rails supported within the sidewalls of the pits or elevated on pedestals so as to permit shop crews to perform various types of maintenance on the underside of cars. The rail shall be secured at the rail base by bolted hold-down rail clips.

5.3.6 Transition Slab Track

Transition slab track shall be required where the track types change from direct fixation track to ballasted track. At the mainline track transitions, where the track types change, matching the vertical fastener stiffness of direct fixation track to the track modulus and rail deflection behavior of at-grade ballasted track must be considered. Transition slab design shall include design considerations of TCRP Research Results Digest 79—*Design of Track Transitions*. Transition slab design shall consider the use of buried reinforced concrete transition slabs in the ballasted track section and wider direct fixation fastener spacing in the direct fixation track section. The depth of the approach slab ballast below the concrete crossties and size of ballast shall be reviewed during transition slab design. Concrete crosstie spacing on the transition slab shall be set at the customary 20-inch crosstie centers. The transition from ballasted track to embedded track at the MSF building apron areas and the transition from ballasted to direct fixation track at the car wash facilities will not require transition slabs because of the slow operating speeds at the sites. Transition slab track shall be positioned on tangent track (horizontal and vertical) in accordance with the Trackwork Standard Drawings.

5.4 TRACK GAUGE AND RAIL CANT

5.4.1 Track Gauge

Track gauge for tangent and curve track shall be the standard track gauge of 4 feet 8½ inches, measured between the inner (gauge) sides of the rail heads at a distance of 5/8 inch below the top of rail plane.

Track gauge widening will not be a requirement on the track system. Track gauge and special trackwork (frogs) flangeway dimensions and guard rails in special trackwork shall conform to the Trackwork Standard Drawings. Passenger vehicles shall be fitted with appropriate wheel profiles and wheel gauges to match the flangeway criteria. Road crossings, guideway emergency walkway crossings, and staff/pedestrian crossings requiring top-of-rail interface shall be slightly depressed (1/4 inch) so as not to be affected by interfacing hollow worn passenger vehicle wheels and highway vehicle rubber tires. Any such crossings shall also be designed to accept highway truck loadings so as not be damaged by highway vehicle rubber tire loading.

5.4.2 Rail Cant

Mainline and yard track rails shall be positioned with an inclination (or rail cant) of 1 in 40 from the vertical toward the gauge side of the rail head. Rail cant shall be developed in the rail seat area of the concrete crossties and within the design of the direct fixation fasteners, unless specifically designed otherwise to suit fastener type.

Within special trackwork areas, rail cant shall not be provided. All special trackwork rail and components shall be installed vertically with no inward inclination. The rail head configuration within the frog design shall be in the vertical position.

5.5 WHEEL PROFILE AND WHEEL GAUGE

The Project vehicle will use a “worn wheel” contour based on the Association of American Railroads (AAR) standard AAR-1B narrow flange wheel profile with slight wheel profile and width modifications. Back-to-back wheel gauge on all revenue service vehicles and maintenance-of-way equipment wheel sets may require specific criteria and not be the same. Specific back-to-back distances shall be shown on the Trackwork Standard Drawings.

5.6 TRACKWORK COMPONENTS

5.6.1 General

Development of trackwork component details shall include consideration of maintainability, reliability, parts standardization, capital costs, and maintenance costs. Maintainability and reliability are of particular importance since train frequencies make it impossible to maintain track during normal operating hours. Parts standardization is also important in that it allows inventories to be minimized and promotes mass production by suppliers, thereby reducing unit costs and enabling transit systems to buy "off the shelf" items.

The essential elements of trackwork expected on this project are as follows:

A. Roadbed, sub-ballast and ballast

B. Rail

C. Crossties and special trackwork (turnout) switch-ties

D. Insulated rail joints—bonded (glued) type

E. Restraining rails (check rails) for curved track

F. Direct fixation rail fasteners

G. Direct fixation special trackwork fasteners for mainline

H. Derails

I. Special trackwork

J. Special trackwork switch machines

K. Track crossings—pedestrians and roadway

L. Interfacing systems to trackwork

M. Friction buffer stops—mainline tracks

N. Sand pit (stops)—yard tracks

5.6.2 Roadbed, Sub-Ballast, and Ballast

The ballasted mainline and yard roadbed structure includes the subgrade, sub-ballast, and ballast to support the track and special trackwork crossties and rail with associated other track materials.

5.6.2.1 Roadbed Subgrade and Soils Engineering

The subgrade is the finished surface of the roadbed below the sub-ballast, supporting the loads transmitted through the rails, crossties, and ballasts. The subgrade shall be analyzed to determine whether it has both uniform stability and the strength to carry the track loadings expected. AREMA recommends that, for most soils, pressure on subgrade be lower than 25 pounds per square inch to maintain subgrade integrity. Uniformity is important because it is differential area spot settlement rather than total settlement that leads to unsatisfactory track alignment. The use of geotextiles or geogrids between the subgrade and sub-ballast can be advantageous under some conditions. Special treatment of the subgrade by injection may be required to achieve the required subgrade integrity.

The subgrade surface shall be sloped 48:1 downward away from the centerline of the track in single track areas and from the midpoint between tracks in multiple track areas to the drainage points. Special trackwork turnouts and fan arrangement areas will be investigated for the need to have a double layer of impervious geotextile placed on top of the subgrade prior to placement of sub-ballast for subgrade reinforcement. Drainage of any geotextile surface must be included in the trackbed design.

The subgrade shall be compacted to at least 95 percent of the maximum dry density as determined by ASTM D 698 (Proctor Test). If the existing material is unsuitable, or the compaction requirements cannot be achieved, the surface material shall be removed to an adequate depth and replaced with clean, sound granular material and compacted to meet the density requirements and subgrade integrity.

Note: Subgrade integrity requirements using materials from Hawaii must be closely monitored.

5.6.2.2 Sub-Ballast

The sub-ballast for all tracks shall consist of a uniform layer placed and compacted over the entire width of the subgrade following the profile and cross-section thereof. The minimum depth of sub-ballast measured from the top of the subgrade shall be 8 inches under the rails in track embankments. Additional depth may be used when necessary to decrease subgrade pressure in border-line subgrade locations. Where widened embankment sections for service roads are provided, the full depth of the sub-ballast shall be extended across the full embankment width, including the service road portion.

The minimum 8-inch layer of sub-ballast shall be installed on top of the subgrade on the mainline and yard lead and yard tracks,. The sub-ballast layer shall parallel the sloped 48:1 sub-grade slope. The configuration of the yard embankment and sub-ballast placement shall provide adequate body track layout drainage. Sub-ballast shall be crushed stone in accordance with ASTM C29, C136, and D15, as well as site-specific additional design requirements. Sub-ballast depth will be 6 inches in the yard.

Note: At this time, it is uncertain whether Hawaii's normal volcanic strata will be suitable for use as sub-ballast due to texture, strength, and chemical content. Chemical content refers to a potential cement/alkali reaction between the island's sub-ballast stone and the concrete crossties and possibly the ballast stone. It may be necessary to import compatible sub-ballast from the Mainland.

5.6.2.3 Ballast

Ballast is a selected crushed and graded hard aggregate material placed upon the sub-ballast to provide support for distributing the track load to the subgrade. AREMA states that the depth of ballast (plus sub-ballast) must be sufficient to distribute pressure between the underside of the crosstie and the top of the subgrade without overstressing the latter. The ballast section must sustain and transmit static and dynamic loads in three directions (transverse, vertical, and longitudinal) and distribute those loads uniformly over the subgrade.

The prime functions of the ballast are to drain the track system, distribute the rail vehicle loads to the subgrade, and hold the track in proper horizontal alignment, cross level and vertical grade. It can also cushion the ride and isolate from the subgrade any vibrations that originate at the rail/wheel interface. It also permits relatively easy adjustment of the track alignment. The gradation and shape of the ballast stone must provide the means to develop the stability and density requirements for the ballast section and provide the void space necessary to allow proper runoff of precipitation.

For the mainline , the minimum depth of ballast measured from the top of sub-ballast to the underside of the track crosstie shall be 10 inches. In curved super-elevated track, the minimum depth of ballast shall be 10 inches measured under the low rail of the inside track in dual track locations, or under each individual track low rail when top-of-rail planes are not continuous. The top of ballast shoulder shall extend a minimum of 12 inches beyond the end of the crossties on standard tangent and curved track, parallel to the plane formed by the top of rails, and leveling out adjacent to retaining walls and barriers. The top of ballast minimum clearance below the base of the rail shall be 1 inch to provide electrical insulation from the ballast. For the yard tracks , the minimum depth of ballast measured from the top of sub-ballast to the underside of the track crosstie shall be 8 inches.

The ballast shoulder shall extend a minimum of 12 inches beyond the end of the switch-ties on special trackwork, parallel to the plane formed by the top of rails, and leveling out adjacent to retaining walls and barriers.

Ballast gradation conforming to AREMA Size 3 shall be used with concrete crossties. Ballast for concrete crossties must be limited to crushed granites, trap-rocks, or specific hard quartzite. Processed ballast must be washed and/or re-screened as necessary to remove fine particle contamination as defined by the specification. Ballast shall conform to the *AREMA Manual for Railway Engineering,* Chapter 1, Part 2. Quality of ballast specific to sieve analysis and gradation values shall be emphasized in the Ballast Specification.

In selected ballasted track areas where routine track maintenance is to be performed, a top layer of No. 5 ballast-size stone will be placed to form a surface walkway. Topping with smaller aggregate No. 5 ballast will be determined as the track design progresses.

Note: Hawaii's normal volcanic strata may not be adaptable for use as ballast because of its texture, strength, and chemical content. The strong possibility exists that ballast may have to be obtained from the mainland. Chemical content refers to a potential cement/alkali reaction between the island's sub-ballast stone and the concrete crossties and possibly the ballast stone.

5.7 RAIL

5.7.1 Rail Section and Material Properties

The rail section for all Project tracks shall be 115RE in accordance with all requirements of the current *AREMA Manual for Railway Engineering,* Chapter 4.

5.7.2 High Strength Rail

The 115RE running rails for the Project shall be High Strength Rail (370 BHN minimum surface) in accordance with the current *AREMA Manual for Railway Engineering*, Chapter 4, Part 2.

5.7.3 Rail Welding

5.7.3.1 Electric (Pressure Flash Butt) Welding

Electric (Pressure Flash Butt) rail welding shall be undertaken to connect both 115RE short stick rails to form continuous welded rail (CWR) strings and the CWR strings to form completed rail installation in track. Electric (Pressure Flash Butt) rail welding shall conform to current *AREMA Manual for Railway Engineering*, Chapter 4, Part 2 requirements relevant to pressure electric welding of rail and the additional requirements listed herein.

All joints in running rails shall be welded, except insulated joints and certain joints in turnouts as at the switch heel block assembly.

Rails shall not be torch cut. Rail cuts shall be made with rail saws or abrasive discs designed for cutting of rails

No holes shall be allowed to remain in the rail. Stick rails shall be welded into the longest CWR strings practicable by the electric (pressure flash-butt) welding method.

5.7.3.2 Thermite (Field) Welding

Thermite (field) welding shall be undertaken to connect both continuous electric pressure welded rail strings to end limits of special track components and special trackwork stick rail within the immediate turnout and crossing layout areas. Thermite (Field) welding shall conform to the current *AREMA Manual for Railway Engineering,* Chapter 4, Part 2 requirements relevant to Thermite welding of rail and the additional requirements listed herein. Thermite welds shall be undertaken by the manufacturer's and welding industries' welding process.

5.7.4 Rail Lubricators

Wayside rail lubricators shall be considered (if not elected to be placed on the vehicle) for installation on all curves with a radius less than 750 feet and in other locations of expected high rail wear and wheel noise. The design of lubricators shall consider high rail gauge face lubrication and low rail head surface friction modifiers. Consider low rail application through the centerline of rail head. Restraining rail installations shall require guard face lubrication to mitigate wheel/rail noise. The reservoir for non-petroleum-type lubricant tanks for rail lubricators must be included within the track design and guideway structure.

5.8 CROSSTIES AND SPECIAL TRACKWORK (TURNOUT) SWITCH-TIES

5.8.1 Concrete Crossties for Ballasted Yard Track

Monoblock concrete crossties are the preferred crosstie for ballasted yard track and special trackwork turnout switch-ties. The concrete crossties and switch-ties shall meet the requirements of the *AREMA Manual for Railway Engineering,* Chapter 30.

Monoblock concrete crossties shall be provided for both ballasted mainline and yard track installations. Two configurations of the crosstie are required. The crossties shall provide design requirements for the following crosstie types:

A. Standard traction power crosstie with embedded shoulders for running rail and embedded inserts for contact rail pedestal extension plate mounting

B. Standard traction power and restraining rail crosstie with embedded shoulders for running rail and embedded inserts for restraining rail bracket and contact (third) rail pedestal extension plate mounting

All crossties shall be designed for standard track gauge and be 8 feet 3 or 6 inches long to accommodate the extension plate contact rail mounting pedestal inserts. Monoblock concrete crossties shall incorporate the lateral resistance patterns on the sides of the crosstie. Crosstie design shall incorporate the 1:40 inward rail seat cant for running rail.

5.8.1.1 Crosstie Rail Fastenings

Fastenings for concrete crossties shall use an insulated boltless, combination cast shoulder and snap-in type rail fastening spring clip, such as the Pandrol e clip. Selected rail clip design shall be applied parallel to the rail instead of perpendicular to the rail type because of limited lateral clearance to the traction electrification contact rail and cover board. Concrete crossties shall have an elastomeric rail seat pad placed between the underside of the rail and the bearing surface of the crosstie. The threaded inserts for traction power pedestal mounting and restraining rail bracket installations shall be of steel and nylon liner insulated design. Running rails shall be insulated from the clip.

5.8.1.2 Crosstie Spacing

Concrete crosstie spacing shall be between 27 and 30 inches for yard tracks in curved track and tangent track, respectively. At locations requiring wider spacing to accommodate other track materials, such as insulated joints, impedance bond box installations, and cable tray troughs, the crosstie spacing may vary up to 36-inch crosstie spacing to allow for these types of installations.

5.8.2 Concrete (Turnout) Switch-Ties for Special Trackwork

Mainline and yard special trackwork switch-ties shall be concrete and range from 9 feet to 17 feet in length. All switch-ties except those in the immediate switch area shall be designed to accommodate the extension plate contact rail mounting pedestal inserts at both ends of the switch-ties. Longer switch-ties will be required for power switch machine (types) and, if required, manual switch stands. Length of switch-ties shall be determined by the switch-tie manufacturer to suit the Trackwork Standard Drawings.

All concrete switch-ties shall be designed for standard track gauge throughout the turnout. Switch-tie rail seat areas shall be level with no rail cant.

Monoblock concrete switch-ties shall be provided for the ballasted mainline and yard special trackwork installations. Many configurations of switch-tie are required. The switch-ties shall provide design requirements for the following switch-tie types:

A. Switch-tie with embedded anchor inserts for switch plates only in immediate switch area.

B. Switch-tie with embedded anchor inserts for switch plates and embedded inserts for switch machine or switch stand.

C. Switch-tie with embedded anchor inserts for switch, frog, and guard rail plates and extension plate contact (third) rail pedestal mounting (contact rail extension plate for pedestal mounting shall be at both ends of switch-tie).

D. Switch-tie with embedded shoulders for running rail (zero cant) and embedded anchor inserts for extension plate contact rail pedestal mounting (contact rail extension plate for pedestal mounting shall be at both ends of switch-tie).

E. Transition switch-ties shall be provided with embedded shoulders for running rail at a rail seat cant 1:80 with embedded anchor inserts for contact rail pedestal mounting (contact rail extension plate for pedestal mounting shall be at both ends of transition tie). These transition ties shall be placed in pairs where special trackwork switch-ties interface with standard crossties with 1:40 rail seat cant.

5.8.2.1 Switch-Tie Rail Fastenings

Fastenings for concrete switch-ties with embedded shoulders shall use a boltless, snap-in type rail fastening spring clip, such as the Pandrol e clip. Concrete switch-ties shall have an elastomeric rail seat pad placed between the underside of the switch and frog plates or rail base and the bearing surface of the switch-tie. The embedded threaded inserts for all plates, switch machines, and extension plate installations shall be of steel and nylon liner insulated design, as shown on the Standard Trackwork Drawings. A special modified e clip will be required for switch-ties at bonded insulated joints for joint bar clearance.

5.8.2.2 Switch-Tie Spacing

Concrete switch-tie spacing shall be nominally 24 inches for switch and frog locations with a tolerance to allow switch rod installations between switch-ties. Other switch-tie spacing throughout the special trackwork shall be in accordance with applicable Trackwork Standard Drawings for turnouts and ladder track arrangements.

5.9 INSULATED RAIL JOINTS—BONDED (GLUED) TYPE

Wherever it is necessary to electrically isolate contiguous rails from each other to comply with train control or traction electrification criteria, insulated rail joints shall comply with the following parameters:

A. Identical rail drilling six-hole standard AREMA pattern shall be implemented unless specifically called for in the Trackwork Standard Drawings, as at the switch heel block location

B. Compatible with the standard rail fasteners used on the Project

C. Comply with the current *AREMA Manual for Railway Engineering,* Chapter 4, Part 2, "Specifications for Quenched Carbon Steel Joint Bars and Forged Compromise Joint Bars," "Rail Drillings & Bar Punching," and “Specifications for Bonded Insulated Rail Joints”

All insulated joints should be located as suspended joints to obviate the need for insulated direct fixation fastener rail base pads and rail seat pads at special trackwork fasteners. Special modified elastic clips may be required at insulated joint locations. Insulated joint bolts shall be equipped with self-locking nuts.

Insulated joint bars of the epoxy bonded (glued along the rail web type) shall be used at all CWR insulated rail joints. The insulated joint bar shall be the "D" type section providing base clearance for modified elastic clip type rail fastenings.

5.10 STANDARD BOLTED RAIL JOINTS IN MAINLINE

Standard bolted rail connections are not anticipated on the Project.

5.11 COMPROMISE RAILS AND COMPROMISE JOINTS

Compromise rails and compromise joint bolted rail connections are not anticipated on the Project.

5.12 RESTRAINING RAILS (CHECK RAILS) FOR CURVED TRACK

Restraining rails for tracks with sharp curves shall use the 33C1 rail section (also referred to as U69, UIC-33 and Ri1-60) with accompanying mounting bracket and accessory shims, bolts, nuts, and washers, as shown on the Trackwork Standard Drawings. The installation of restraining rail will reduce the rate of rail wear to the outside high rail gauge face in curved sections. In addition, restraining rail will eliminate the tendency of lead axle outside wheel from wheel climb as the rail gauge face conforms to wear patterns. Restraining rail shall be installed in the following locations:

A. Mainline tracks with a track centerline radius of 650 feet or less

B. Yard lead track and access ladder track with a centerline radius of 250 feet based on the slower speeds on these tracks

C. Restraining rail shall extend through the central and spiral portions of the track curvature and beyond a minimum distance of one axle spacing of the longest axle spacing truck

D. Restraining rails shall be mounted separately by bracket from the 115RE running rail and insulated for traction power

E. The 33C1 restraining rail mounting bracket shall be designed with insulated anchor bolts, collars, and polyurethane base pads

F. At running rail insulated joints, the concrete crosstie spacing or the direct fixation fastener spacing shall be mounted wider to accommodate the installation and mounting of a restraining rail insulated joint directly opposite the running rail insulated joint.

5.13 EMERGENCY GUARD RAIL

Emergency guard rail is not a requirement on the Project.

5.14 DIRECT FIXATION RAIL FASTENERS

Direct fixation rail fasteners for aerial structures, at-grade direct fixation track, and yard shop wash-track shall be designed for transit loadings. They shall provide the required lateral and longitudinal restraint for continuous welded rail and the electrical insulation required for the negative return current and the proper operation of track signal circuits. Direct fixation fastener systems considered for this Project may include neoprene elastomers, bonded and vulcanized rubber/steel fasteners, and special noise attenuation designed systems where the rail is supported by the rail web area only. Resilient fasteners to restrict both noise and vibration due to wheel/rail interface shall be incorporated into the fastener design. More than one type of resilient fastener may be a requirement to meet the specific Environmental Design Criteria for the various sections along the track system.

Spacing between direct fixation rail fasteners shall not be greater than 30 inches unless specifically required to accommodate installation of interfacing component requirements, such as insulated joints, impedance bond box mountings, and aerial structure expansion joint locations.

Direct fixation fastener performance requirements shall include the following:

A. Direct fixation rail fasteners shall provide an average longitudinal restraint force of 2,400 pounds per fastener and restrain a broken rail gap width to less than 2-1/2 inches

B. Direct fixation rail fasteners shall provide a spring rate of between 94,000 pounds per inch and 200,000 pounds per inch for vertical loads between 4,500 pounds and 12,000 pounds

Aerial structure specific design may require low-restraint fasteners to allow the structure to expand and contract unimpeded and without overstressing the rail.

The relationship that the plane of the running rails and the centerline of track have with the contact rail is fixed as shown on the standard drawings. However, the elevation of the direct fixation track slab relative to top of rail can vary depending on the thickness of the rail fasteners. If the contact rail is supported from the same concrete plinths as the running rails, the Designer must consider the overall height of the rails, fasteners and any shims so as to achieve the proper vertical difference between the running rails and the top surface of the contact rail.

5.15 DIRECT FIXATION SPECIAL TRACKWORK FASTENERS FOR MAINLINE

Premium bonded direct fixation fasteners will be incorporated into the mainline special trackwork design. Direct fixation special trackwork fasteners shall be designed for the use of standard curved 5100 (Samson) switch point rails undercut stock rails, solid manganese frogs and 33C1 type guard rails to the extent that this does not compromise performance or maintainability. To this end, fastener locations and spacing on direct fixation components should match tie centerline locations on similar-sized ballasted turnout components wherever practicable.

Conventional switch gauge plate design shall not be incorporated into the design of direct fixation or ballasted concrete switch-tie design.

The type of rail fastening spring clip used within the special trackwork areas shall match the concrete crosstie fastenings and the mainline direct fixation fasteners.

The interface between the special trackwork direct fixation track and the contact rail must consider issues noted in Article 5.14 relative to standard direct fixation fasteners.

5.16 DERAILS

Split switch point derails shall be used to prevent out-of-control cars/train from fouling adjoining or adjacent mainline or transfer tracks. Derails should be installed in the yard on the downgrade end of the yard lead track if this track is directly connected to a mainline track and if the prevailing grade is descending toward the mainline track.

Derails shall be placed beyond the clearance point so as not to interfere with mainline and transfer track operations should a derailment occur. Derail shall be located so as to derail equipment in the direction away from the main track. Refer to Trackwork Standard Drawings for typical yard locations of derails.

If the yard lead track(s) ascend toward connections to the mainline and/or transfer tracks, thereby not allowing out-of-control cars/train to drift toward the mainline and transfer tracks, derails will not be required.

Split point derail design shall include an entire 13-foot curved switch assembly with bolted heel block on concrete switch-ties and power operated switch machine similar to the standards of the No. 6 yard track turnouts.

5.17 SPECIAL TRACKWORK

5.17.1 General

The Project system contains three types of specific special trackwork: direct fixation and ballasted special trackwork for the mainline and ballasted special trackwork both with concrete switch-ties for the mainline and MSF yard.

Turnout designs shall meet the requirements of the *AREMA Portfolio of Standard Plans*, where applicable, except as modified herein. Turnouts shall be of 115RE high strength rail and AREMA standard frog number sizes. The preferred frog numbers shall be No. 6 and Nos. 8 in the yard, with10, and 15 turnouts along the revenue line. The special trackwork shall be developed as single turnouts, single crossovers, and double crossover arrangements. Solid manganese contoured frogs shall have tangent geometry for No. 6, 8, 10, and 15 turnouts. In the event that other unique special trackwork designs must be developed to address site-specific conditions, the trackwork shall be designed to use standard switch point rails, stock rails, frogs, and guard rails wherever practicable to minimize inventory.

5.17.2 Rail Section and Layout

All turnouts shall be designed for the 115RE rail section for mainline tracks and yard tracks. All rails in turnouts and crossovers shall be high strength head hardened rails.

The rail layout shall be such that joints or rail welds in opposite rails on the same track do not occur in the same tie or fastener crib line. Joint stagger shall be single switch-tie or fastener space or greater, to the extent practical. The same rail layout shall be used for similar-numbered turnouts for both direct fixation and ballasted turnouts.

5.17.3 Insulated Rail Joints and Other Rail Joints

All insulated joints within the turnouts and crossover arrangements shall be field-made, bonded (glued) insulated rail joints. All other rail joints within the turnout and crossovers shall be thermite field welded. The only bolted rail joints on the Project system shall be at the five bolt heel block assembly for No. 6 Ballasted Special Trackwork at the yard installation.

5.17.4 Turnouts, Crossovers, and Double Crossovers

The type of turnouts on the Project system and length of switch point rails shall be as follows:

A. No. 6 ballasted turnouts: in the yard to be designed with 13-foot curved split switch

B. No. 8 ballasted turnouts: in the yard to be designed with 19-foot-6-inch curved split switch

C. No. 10 direct fixation turnouts single and double crossovers: on mainline track to be designed with 19-foot-6-inch curved split switch

D. No. 10 ballasted turnouts and crossover: on the mainline track to be designed with 19 foot 6 inch curved split switch.

E. No. 15 direct fixation turnouts: at the west junction for Salt Lake/Airport tracks to be designed with 26-foot-0-inch curved split switch

5.17.5 Switch Machines for Mainline and Yard

Switch machines for mainline use shall be power operated with switch-and-lock movement operation integrated with the system design. The machine shall be provided with a hand throw lever and hand crank. Mechanical locking shall be in place during hand operation. The machine shall be similar in design to the M23A (Union Switch and Signal, an Ansaldo-affiliated company) or the 5F (Alstom Signaling).

Switch machines for yard use shall be power operated, trailable, hand crank or lever design similar to Alstom Signaling Inc. Model 6.

Manual switch stands for yard use shall be spring operated, trailable, level lock design similar to Abex Model 22 with targets.

5.18 TRACK CROSSINGS—PEDESTRIAN AND ROADWAY

5.18.1 Emergency Pedestrian Track Crossings—Mainline

The aerial guideway with direct fixation track shall include designated emergency walkways for pedestrians evacuating non-functioning vehicles or trains. The walkways shall be located in a manner requiring the crossing of the mainline tracks. The crossing panels shall be configured to accommodate and provide clearance with the direct fixation track installation and be bolted in place. The crossing panel surface shall be ¼-inch below the top of rail head. The gauge side flangeway shall be 2½-inch wide.

The crossing outline edges shall be clearly delineated with an 8-inch-wide yellow marker line. The inside face of the open flangeway shall be similarly painted in yellow to draw attention to the open flangeway.

5.18.2 Pedestrian Track Crossings—Yard

The MSF yard shall include designated pedestrian walkways for access to and from designated parking areas. The walkways may be located in a manner requiring the crossing of the yard tracks. Pedestrian crossings shall be designed using standard full-depth concrete crossing panel sections to provide relatively easy access. The crossing panels shall be configured to accommodate and provide clearance with the ballasted concrete crosstie fastening installation and be secured in place. The crossing panel surface requiring top of rail interface shall be ¼-inch below the top of rail head so as not to be affected by interfacing hollow worn vehicle wheels and hyrail vehicle rubber tires. The gauge side flangeway shall be 2½-inch wide.

The crossing outline edges shall be clearly delineated with an 8-inch-wide yellow marker line. The inside face of the open flangeway shall be similarly painted in yellow to draw attention to the open flangeway and tripping hazard. The pedestrian crossing width shall be 2 feet wider on each side measured from the inside face of the delineated walkway.

5.18.3 At-Grade Ballasted Road Crossings—Yard

The MSF yard shall include designated roadways with road crossings for complete yard access. The roadways will be located in a manner requiring the crossing of single or multi-yard track arrangements. The road crossings shall be designed using standard full-depth concrete crossing panel sections to provide a relatively smooth crossing and access. The crossing panels shall be configured to accommodate both tangent and curved track and provide clearance with the concrete crosstie track installation and be secured in place. The crossing panel surface shall be 1/4-inch below the top of rail head so as not to be affected by interfacing hollow worn passenger vehicle wheels and highway vehicle rubber tires. The gauge side flangeway shall be 2½-inch wide.

The roadway crossing (traveled portion) outline edges shall be clearly delineated with a 12-inch-wide yellow marker line. The roadway crossing width shall be 2 feet wider on each side, measured from the inside face of the delineated roadway.

Roadway crossings that also include a pedestrian crossing shall have both edges of the actual walkway clearly delineated with a 12-inch-wide yellow marker line. The total crossing width shall be 2 feet wider on each side measured from the inside face of the delineated walkway. The inside face of the open flangeway in the walkway area only shall be similarly painted in yellow to draw attention to the open flangeway.

5.19 INTERFACING SYSTEMS TO TRACKWORK

5.19.1 Traction Electrification—Impact on Track

The interrelationship of the trackwork design to the design of the traction electrification system must be included in the total design process. The design selected for the traction electrification elements will affect the design parameters for trackwork; therefore it is vital for the trackwork designer to fully understand how the other elements will affect the design of the track structure.

The purpose of the traction electrification distribution system (contact rail) is to conduct positive current from the substation to the vehicle current collector paddle. The track system running rails will form the return side (negative return) of this distribution circuit back to the substation. The negative return usually consists of both running rails.

All bolted joints or bolted rail assemblies in the negative return rail segments shall be electrically “bonded” across the joint bars or bolted rail assemblies with high conductivity cable bonds. The negative return rails of parallel tracks should be cross-bonded frequently to equalize the currents that traverse the rails. In segments that use both running rails for return, all rails of parallel tracks should be crossbonded. The locations of crossbonding and negative return cables to the substation shall be identified for the track designers by the traction electrification system designer, working in conjunction with the train control system designer.

Another prime example of the interrelationship between trackwork and negative return is the need for bonded (glued) insulated rail joints in the running rails to separate adjacent traction power substation negative return in the rails. The location of the insulated joints must be coordinated to accommodate the train control requirements. If signal train control design is included in the rail system, impedance bonds will also be required at the insulated rail joint locations, which the track designer must consider.

All rail joints and electrical track connections must be electrically "bonded." With the exception of any temporary connections, an exothermic process (Cadweld or Thermoweld) shall be used for cable or wire size below 250 thousand circular mils (kcm). Bolted rail web connections (Cembre type) shall be used for cables 250 kcm and above. The rail bond connections must only be welded or applied to the rail web 2.98 inches (plus or minus 1/16 inch) above the base of rail at the neutral axis as noted in the Standard Trackwork Drawings. Rail head bond and rail base bonds are prohibited. The rail bond installation/attachment process must fully adhere to the manufacturer’s instructions and recommended procedures for installation.

All track on the Project system is to be operated using direct current (DC) traction electrification (i.e., tracks to be equipped with contact rail). Appropriate measures shall be taken during the design of all types of trackwork, including embedded track and yard at-grade crossings, to minimize leakage of electrical negative traction power (known as stray current) from the rails to the aerial structure, the ballast, and the ground. This work shall be consistent with system corrosion control requirements. Embedded track will be protected as shown in the Trackwork Standard Drawings. Refer to Chapter 17, Corrosion Control, for details on stray current and corrosion control requirements.

5.19.2 Signaling and Train Control—Impact on Track

Train control design may adversely affect selected trackwork design concepts. A prime example in interrelationship is the need for bonded (glued) insulated rail joints in the running rails to accommodate train control requirements. Such joints are normally required at the extremities of interlockings; within individual turnouts, crossovers, and double crossovers; at each end of station platforms; and at other locations to be determined by the train control design.

The location of the insulated joints must be coordinated to accommodate the train control requirements. If negative return and signal train control design is included in the rail system, impedance bonds will also be required at the insulated joint locations, which the track designer must accommodate in the track design.

All rail joints and electrical track connections must be electrically "bonded." With the exception of any temporary connections, an exothermic process (Cadweld or Thermoweld) shall be used for cable or wire size below 250 kcm. Bolted rail web connections (Ciembre type) shall be used for cables 250 kcm and above. The Cadweld or Ciembre connections must only be welded or applied to the rail web 2.98 inches (plus or minus 1/16 inch) above the base of rail at the neutral axis as noted in the Standard Trackwork Drawings. The Cadweld process or Ciembre installation must fully adhere to the Cadweld or Ciembre kit manufacturer’s instructions and procedures on installation and recommendations.

Insulated rail joints at limits of track circuits are to be opposite each other (staggered between 32 and 54 inches) to increase signal reliability and facilitate underground ducting and traction power crossbonding.

Shunt fouling limit cable connections and train to wayside communication loop detectors may also be required. Installation details for the various types of track are essential. The detector assembly must be mounted and secured in a permanent position to the track structure.

5.20 FRICTION BUFFER STOPS—MAINLINE AND TRANSFER TRACKS

Friction buffer stops shall be a requirement and permanently placed at the ends of the mainline tangent track. Friction buffer stops shall also be required as temporary tangent track installations for segmental sections of track for interim partial line operations. The intent is to relocate the temporarily placed buffer stops as the Project’s operational system expands. The friction buffers shall be capable of stopping a four-car train without damage to any of the cars at a speed of 10 miles per hour. The friction buffers shall have a hydraulic ram to absorb slow speed impacts of 3 miles per hour or less. Only the friction buffer head shall contact the car. Contact between the car and the buffer head shall not cause lifting or derailment of the car. Friction buffer shoes shall extend past the buffer housing to the extent necessary to stop the car or train. Additional running rails may be required beyond the buffer stop layout to halt the train in a controlled deceleration mode.

At temporary ends-of-track locations, sufficient guideway structure with direct fixation track shall be constructed to safely control stopping of the train should an accidental run-through occur. The main intent is to keep the car or train on the elevated initial short segments of the constructed guideway structure.

5.21 SAND PITS—YARD TRACKS

Sand pits shall be placed at the end of all stub-end yard tracks. The sand pit shall be capable of stopping a four-car train at a speed of 5 miles per hour.

END OF CHAPTER

Honolulu High-Capacity Transit Corridor Project

(Project)

DESIGN CRITERIA

CHAPTER 6

CIVIL

May 22, 2009

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6.0 CIVIL

6.1 GENERAL

6.1.1 Introduction

This chapter establishes the basic civil criteria and the related work to be used in the design of the Project and:

A. Includes criteria for the design of the drainage and determination of rights-of-way, control of access, service roads, streets, and site work

B. Establishes the minimum dimensions required for clearances between the transit structures and roadway elements

6.1.2 Related System Interface

This chapter is interrelated to the other chapters of the Compendium of Design Criteria. They should be used collectively to meet the requirements of specifications and design guidelines in accordance with the current practices of the state and the City and County of Honolulu (CCH).

6.2 ROADWAY

6.2.1 Design Standards

The design elements of the Project shall comply with the Local agency having jurisdiction and the latest version of the applicable standards, manuals, policies, codes, regulations, plans, documents, and specifications listed below:

A. American Association of State Highway and Transportation Officials (AASHTO). *Roadside Design Guide.*

B. American Association of State Highway and Transportation Officials (AASHTO). *A Policy on Geometric Design of Highways and Streets.*

C. American Association of State Highway and Transportation Officials (AASHTO). *Roadway Lighting Design Guide.*

D. American Association of State Highway and Transportation Officials (AASHTO). *Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals.*

E. American Association of State Highway and Transportation Officials (AASHTO). *Guide for High-Occupancy Vehicle (HOV) Facilities.*

F. American Association of State Highway and Transportation Officials (AASHTO). *Guide for Park-and-Ride Facilities.*

G. American Association of State Highway and Transportation Officials (AASHTO). *Guide for the Development of Bicycle Facilities.*

H. American Association of State Highway and Transportation Officials (AASHTO). *Guide for the Planning, Design, and Operation of Pedestrian Facilities.*

I. American Association of State Highway and Transportation Officials (AASHTO). *Standard Specifications for Highway Bridges.*

J. American Association of State Highway and Transportation Officials (AASHTO). *LRFD Bridge Design Specifications.*

K. Federal Highway Administration (FHWA). *Manual on Uniform Traffic Control Devices for Streets and Highways.*

L. *ADA Accessibility Guidelines for Buildings and Facilities (ADAAG).*

M. State of Hawaii Department of Transportation (HDOT). *Design Manual.*

N. State of Hawaii Department of Transportation (HDOT). *Standard plans.*

O. State of Hawaii Department of Transportation (HDOT). *Standard Specifications for Road, Bridge, & Public Works Construction Manual.*

P. State of Hawaii Department of Transportation (HDOT). *Design Criteria for Bridges and Structures.*

Q. State of Hawaii Department of Transportation (HDOT). *Curb Ramp and Sidewalk Design Guidelines.*

R. City and County of Honolulu (CCH). Traffic Design Manual.

S. City and County of Honolulu. *Standard Details for Public Works Construction.*

T. City and County of Honolulu. *Standard Specifications.*

U. Transportation Research Board. *Access Management Manual.*

V. Transportation Research Board. *NCHRP Report 420, Impacts of Access Management Techniques.*

W. State of Hawaii Department of Transportation (HDOT). *Bike Plan Hawaii.*

X. City and County of Honolulu (CCH). *Honolulu Bicycle Master Plan.*

6.2.2 Horizontal and Vertical Control

All horizontal and vertical controls shall be based on the horizontal and vertical control system established by the City and County of Honolulu, Department of Transportation Services Rapid Transit Division (RTD) for the Project. Coordinates established for the system shall be in the Hawaii State Plane Coordinate Grid System, North American Datum 83 HARN (PAC00), Zone 3. The accuracy of the primary transit horizontal and vertical ground control network shall, as a minimum, be Second Order, Class II, as defined by the Federal Geodetic Control Committee and published under the title “Classification, Standards of Accuracy and General Specifications of Geodetic Control Stations,” authored by the National Geodetic Survey, dated September 1984.

A. Horizontal Control

1. The accuracy of secondary horizontal ground control network shall, as a minimum, be 1:50,000.
2. All subsequent horizontal surveys shall, as a minimum, have an accuracy of 1:20,000.

B. Vertical Control

Vertical controls for the Project shall be based on the National Geodetic Vertical Datum of 1929.

6.2.3 Basis of Geometric Design Report

Criteria for roadway and geometric elements shall be included in the Designer's Basis of Geometric Design report. This report shall comply with the Local agency having jurisdiction and the applicable standards, manuals, policies, codes, regulations, plans, documents, and specifications. The Designer shall submit the report to the RTD and the respective agency having jurisdiction for review and approval.

A. The report shall document the following roadway and geometric design elements for each affected roadway, including, but not limited to, the following:

1. Design speed and posted speed
2. Design vehicle
3. Functional roadway classification
4. Terrain identification
5. Lane widths
6. Cross slopes
7. Shoulder widths
8. Sideslopes
9. Median island widths
10. Grades
11. Superelevation
12. Horizontal clearances
13. Vertical clearances
14. Sight distances
15. Curb return radii

16. Traffic lane configuration and widths
17. Parking lanes and dimensions
18. Sidewalk widths
19. Traffic ADT
20. Level of Service (LOS)
21. Clear Zone

6.2.4 Roadway Geometrics

6.2.4.1 General Elements

A. Traffic Lanes

The number and type of traffic lanes (i.e., through, right, or left) shall be determined in consultation with the appropriate agency having jurisdiction, generally based on a traffic analysis which considers projected traffic volumes, Level of Service (LOS), critical traffic movements, and geometric configurations. In all cases, the number of lanes shall not be less than the number available that exists prior to construction.

6.2.4.2 Cross-Sectional Elements

A. Lane Width

The following criteria indicate maximum, minimum, and desirable values for traffic lane widths. In cases of significant constraint, a width reduction may be necessary.

1. Through lanes (multiple): 12 feet preferred, 11 feet minimum
2. Through lane (single): 14 feet preferred, 12 feet minimum
3. Through lane (outside): 15 feet preferred*, 14 feet minimum *
4. Right turn lane: 11 feet preferred, 10 feet minimum
5. Left turn lane(s): 11 feet preferred, 10 feet minimum
6. Parking lane: 10 feet preferred, 8 feet minimum
7. Bike lane: 5 feet preferred, 4 feet minimum

*-Outside through travel lane width with a signed shared use bicycle lane.

B. Parking Lanes

Parking locations shall be determined in consultation with the appropriate agency having jurisdiction based on traffic analysis, safety considerations, and demand for on-street parking. A 24-hour parking prohibition shall be recommended at those locations (i.e., near intersections) where roadway width is not adequate to provide the necessary number of through lanes. Peak-hour parking prohibitions shall be recommended at those locations where traffic analysis shows that the capacity of the traveled way without the parking lane will provide Level of Service D or worse. The Designer shall coordinate mitigation measures for any lost on-street parking with the appropriate agency having jurisdiction.

C. Cross Slope

The following criteria indicate maximum, minimum, and desirable values. The cross slope at roadway widening locations shall match that of the existing roadway whenever possible.

1. Normal crown (roadways): 1.5 to 3 percent, 2 percent preferred
2. Through lane (outside): Varies
3. Aggregate surface pavement: 3 percent
4. Parking areas: 1 percent minimum; 5 percent maximum
5. Shoulders: 4 percent maximum

D. Horizontal Clearance

The following criteria indicate the minimum values for horizontal clearances calculated as the horizontal distance between the edge of travel way and the obstruction.

1. Column: 3 feet
2. Roadside obstacle without curb: Varies**
3. Roadside obstacle with curb: 1.5 feet *
4. Bridge parapets, rail, or barrier: Varies **
5. Clear Zone: Varies **
6. Shy Line Offset: Varies **

* Minimum horizontal distance between the top, front face of curb to fixed object.

** See the AASHTO Roadside Design Guide for values.

E. Vertical Clearance

The following criteria indicate the minimum vertical clearances calculated as the vertical distance between the undercrossing surface and the bottom of overcrossing structure.

1. Roadway/transit structures: 16.5 feet
2. Pedestrian bridges: 17.5 feet

F. Sidewalks

The following criteria indicate maximum, minimum, and desirable values for new sidewalks. All sidewalks shall be sloped away from the edge of right of way.

1. Cross Slope: 1.5 percent minimum, 2 percent maximum

2. Width: 5 feet minimum

6.2.4.3 Horizontal Geometric Elements

A. Sight Distance

The Stopping Sight Distance (SSD) and Passing Sight Distance (PSD) are based on the type of terrain and the design speed of the roadway.

B. Curb Return Radii

The following criteria indicate the minimum curb return radii measured to the face of curb. Larger radii may be warranted where there is a skewed intersection, narrow alley, or heavy bus/truck usage.

- Roads 35 (ft)
- Municipalities 25 (ft)
- Parking areas 15 (ft)

6.2.4.4 Vertical Geometric Elements

A. Vertical Geometry

The following criteria indicate maximum, minimum values. The vertical profile grade along roadway widening locations shall match that of the existing roadway whenever possible. The vertical grades listed below are based on the roadway classification.

Roadway Classification	Min Profile Grade (%)	Max Profile Grade (%)
Local Road (Rural)	0.5	8.0
Local Road (Urban)	0.5	8.0
Collector	0.5	6.0
Arterial	0.5	6.0

6.2.5 Pavement Design

Pavement structure design shall be in accordance with the State of Hawaii Department of Transportation (HDOT) or the City and County of Honolulu's (City) latest design manual and be based on current geotechnical information. Pavement restoration in public streets shall conform to

HDOT Standard Specifications for Road, Bridge, & Public Works Construction Manual or the standards and specifications of the agency having jurisdiction.

6.2.6 Concrete Bus Pads

Concrete bus pads shall be provided at all bus stops which are reconstructed as part of the Project in conformance with the standards and specifications of the agency having jurisdiction.

6.2.7 Bus Turnouts

Bus turnouts shall be designed in accordance with the following:

A. Bus turnout width: 10 feet minimum; 12 feet desirable

B. Stopping area length (standard vehicle): 50 feet

C. Stopping area length (articulated vehicle): 70 feet

D. Entry taper: 1:5 minimum

E. Exit taper: 1:3 minimum

6.2.8 Vaults

A. The Designer shall identify vaults affected by construction. Details shall show each vault to be removed; new walls required to permit continued use of vaults outside construction limits; new walls to accomplish complete abandonment of vaults, where required; work required to restore vaults, including delivery chutes and freight elevators and the area available for permanent occupancy by the original owner upon completion of construction.

B. The Designer shall coordinate with the owner to determine goods or facilities requiring removal from the vault; how deliveries shall be made to properties when existing vault entrances must be abandoned; and time required taking each of the above enumerated steps. Work shall be coordinated with municipality or agency to avoid construction delay and occupation of the vaults.

6.2.9 Landscape Areas and Street Trees

Work involving street trees and landscaped areas shall conform to specifications, criteria, and practices of the affected municipality's standards involved. Refer to Chapter 11, Landscape Architecture, for additional information.

6.3 DRAINAGE

6.3.1 Design Standards

The design elements of the Project shall comply with the Local agency having jurisdiction and the applicable standards, manuals, policies, codes, regulations, plans, documents, and specifications listed below. Unless specifically noted otherwise herein, the latest edition of the code, regulation, standard, and standard plan that is applicable at the time design is initiated shall be used. If a new edition or amendment to a code, regulation, standard, or standard plan is issued before the design is completed, the design shall conform to the newer edition.

A. City & County of Honolulu. March 30, 2007. *Storm Water Management Plan.*

B. City & County of Honolulu. May 1999. *Best Management Practices Manual for Construction Sites in Honolulu.*

C. City & County of Honolulu. April 1999. *Rules Relating to Soil Erosion Standards and Guidelines.*

D. City & County of Honolulu. January 2000. *Rules Relating to Storm Drainage Standards.*

E. State of Hawaii Department of Transportation Highways Division. March 2007. *O'ahu Storm Water Management Program Plan (SWMPP).*

F. State of Hawaii Department of Transportation Highways Division. March 2007. *Storm Water Permanent Best Management Practices Manual.*

G. State of Hawaii Department of Transportation Highways Division. January 2008. *Construction Best Management Practices Field Manual.*

H. State of Hawaii Department of Transportation Highways Division. May 15, 2006. *Design Criteria for Highway Drainage.*

6.3.2 Hydrology

6.3.2.1 City Drainage Facilities

A. Recurrence Interval

1. For drainage areas of 100 acres or less: recurrence interval (Tm) = 10 years, unless otherwise specified.
2. For drainage areas of 100 acres or less with sump, or tailwater effect, and for the design of roadway culverts and bridges: Tm = 50 years.
3. For drainage areas greater than 100 acres and all steams, design curves based upon the U.S. Geological Survey data on flood magnitude and frequency: Tm = 100 years.
4. For fixed guideway drainage: Tm = 25 years.
5. For drainage areas where downstream facilities are inadequate: Interim measures shall be reviewed on a case-by-case basis.

B. Runoff Quantity

1. For drainage areas of 100 acres or less, runoff quantities shall be determined using the Rational Method.

2. For drainage areas greater than 100 acres and for all streams, runoff quantities shall be determined using Plate 6 titled "Design Curves for Peak Discharge vs. Drainage Area."

3. For drainage areas where downstream drainage system capacities are inadequate to accommodate runoff quantities identified by the methods specified herein, design runoff quantities shall be limited to predevelopment conditions or conditions otherwise specified.

C. Runoff Quality

1. New development and redevelopment projects (i.e., building footprint expansions, structural additions, etc.) which result in a land disturbance of a minimum of 1 acre and smaller projects that have the potential to discharge pollutants to the City's municipal separate storm sewer system shall install permanent storm water best management practices (BMPs). See Post-Construction Storm Water Management Manual, City and County of Honolulu Department of Environmental Services 2008 for exceptions.

2. Permanent storm water BMPs shall be designed, installed, and maintained in accordance with the criteria and guidelines described in the Post-Construction Storm Water Management Manual, City and County of Honolulu Department of Environmental Services, 2008. Types and sizes of permanent storm water BMP will depend upon the runoff quantity and runoff quality to be controlled by the project.

3. Permanent storm water BMPs are intended to remain a part of the Project's features upon completion of construction. Permanent storm water BMPs shall be inspected and maintained in perpetuity in compliance with the requirements of the Authority Having Jurisdiction (AHJ).

6.3.2.2 HDOT Drainage Facilities

A. Recurrence Interval

1. Bridges and Culverts

    a. Freeways and arterial highways

        i. Tm = 50 years to maximum storm of record

        ii. Tm = 100 years for sites covered by National Flood Insurance Program, if practicable

    b. Collector streets and roads: Tm = 25 years

    c. Local roads: Tm = 10 Years.

2. Roadway Drainage

    a. Travel way at sumps:

        i. Freeways: Tm = 50 years

ii. Arterial highways: Tm = 25 years

iii. Collector streets and roads: Tm = 10 years

iv. Local roads: Tm = 10 years

b. Freeways and arterial highways: Tm = 25 years

c. Collector streets and roads: Tm = 10 years

d. Local roads: Tm = 10 years

3. The minimum time of concentration shall be 10 minutes.

4. Refer to the Hawaii Statewide Uniform Design Manual for Streets and Highways for the definitions of the different types of highways.

B. Runoff Quantity

1. Rational Method: For peak discharges in drainage areas up to 200 acres

2. Published Flow Records: For peak discharges in large basins

3. USGS Regression Equations: For peak discharges in medium and large basins

4. Soil Conservation Method: For peak discharges in large watersheds where gage data are not available

5. City and County of Honolulu Method: For the purpose of checking peak discharges only, Plate 6

Where the Designer determines it appropriate, estimated runoff quantities determined by methods specified herein shall be supplemented with field investigation data to determine high water marks, amount and type of ponding, size of culverts, and to evaluate streambed conditions.

Runoff quantities shall be determined using several hydrologic methods, including, but not limited to, those discussed herein. The Designer shall select the most appropriate design discharge for the watershed based on an evaluation of the peak discharge values estimated by the methods specified herein and any supplemental field data.

C. Runoff Quality

1. Any project (new or redevelopment) which generates equal to or greater than 1 acre of new permanent impervious surface shall install permanent storm water BMPs. See Storm Water Permanent Best Management Practices Manual, State of Hawaii Highways Division, March 2007 for exceptions and variances.

2. Permanent storm water BMP shall be designed, installed and maintained in accordance with the criteria and guidelines described in the Storm Water Permanent Best Management Practices Manual, State of Hawaii Highways Division, March

2007. Types and sizes of permanent storm water BMPs will depend upon the runoff quality to be controlled by the project.

3. Permanent storm water BMPs are intended to remain a part of the Project's features upon completion of construction. Permanent storm water BMPs shall be inspected and maintained perpetually in compliance with the requirements of the AHJ.

6.3.3 Design Storm Drainage Area

Area	Storm Frequency (years)
All culverts and drainage ways crossing the rail system where flooding could damage system	100
Track roadbed (to top of subballast)	25
Main storm drains	25 (HDOT) 10/50 (City)
Parking lots	10
All longitudinal drains or subdrains that could flood the roadbed	25 (HDOT) 10/50 (City)
All sump condition areas (defined as low areas which prevent the free passage of water with consequent flooding of streets or private property)	50
All other areas	25 (HDOT) 10/50 (City)

6.3.4 Surface Drainage

A. Plaza area drainage shall be designed to minimize surface water level and velocity to maintain a safe walking surface. Minimum grade shall be 0.5 percent and maximum grade shall be 2.0 percent in open plaza areas. Special drains shall be installed as necessary. Maximum water surface over drains shall be one-half inch. Maximum water velocity in plaza areas shall be 2 feet/second.

B. Parking lots shall be designed to conform to design standards so that storm water is removed by overland flow to a gutter or curb and gutter, then to an inlet, where the water will enter a closed drainage system and per the specifications of the agency having jurisdiction. Overland flow shall be at a minimum of 1-percent grade and shall not run for more than 75 feet before being intercepted by a drainage structure, such as a gutter or a drain. The maximum permissible flow width for gutter in a parking area is 12 feet.

C. Street drainage shall be designed so water surface remains below top of curb and flow width complies with the requirements of the traveled way. Water surface elevation shall be controlled by adding catch basins as necessary. The Designer will follow criteria of the AHJ for each affected facility.

D. A storm drainage system shall be provided along all trackways and at all yards. The system normally consists of a combination of graded subgrade areas and perforated self-cleaning subdrains connected to the necessary laterals, collectors, and outfall structures. A system of ditches, catch basins, and storm drain pipes shall be designed to direct surface runoff away from all track areas and also to handle flow from the subdrain and any roof drain systems. In no case shall a storm drain flow into a subdrain.

1. Yard trackwork areas shall be underlain by a 6-inch minimum layer of semi-impervious subballast properly compacted and graded at a minimum slope of 1:25 to the subdrains. Open surface track and material storage areas also shall be covered with an 8-inch layer of semi-impervious compactable material and shall be graded to area drains at a minimum slope of 1:25.

2. The minimum slope of the drainage system shall conform to the requirements of the AHJ. Where minimum slope requirements are not specified by the AHJ, the drainage system shall contain the following minimum slopes:

   a. Subdrains: 0.50 percent

   b. Laterals: 0.30 percent (0.50 percent for HDOT facilities)

   c. Main collectors: 0.25 percent (0.50 percent for HDOT facilities)

   d. Ditches: 0.25 percent (0.50 percent for HDOT facilities)

3. Cleanouts shall be provided at the terminus of each subdrain. Individual subdrain runs shall not exceed 250 feet.

4. Manholes shall be provided at a maximum interval of 250 feet for pipe sizes 36 inches or less in diameter. Maximum manhole spacing for pipes larger than 36 inches in diameter and for box culverts shall be 500 feet.

6.3.5 Drainage Structures

A. Drainage structures shall be designed special structures. Use of agency standards is permissible. The Designer shall follow applicable Federal Highway Administration Hydraulic Engineering Circulars for State-owned systems.

B. Drainage structures for parking lots shall be selected from the standard storm drain details of the jurisdiction in which the parking lot is to be constructed. Inlet structures should not be located adjacent to bus pads, on-site bus stops, or where patrons would normally be picked up or dropped off by vehicles other than local buses.

C. A sufficient number of inlets shall be provided to intercept the surface drainage. Inlets on grade shall be designed to intercept 85 percent or more of the design flow. Inlets in sump areas shall be designed to intercept 100 percent of the design flow. The amount of flow intercepted by an individual inlet shall be determined by the procedures outlined in the manual entitled “Design of Storm Water Inlets,” published by the Johns Hopkins University, Department of Sanitary Engineering and Water Resources, June 1956, or standards of the AHJ.

6.3.6 Storm Drains

6.3.6.1 Closed Conduit

A. Manning's Formula for selecting pipe size is:

$$Q = 1.486 (AR^{2/3} S^{1/2}) / n$$

$$V = 1.486 (R^{2/3} S^{1/2}) / n$$

Where:

Q = Quantity of full flow capacity, cfs

A = Area of conduit, feet^2
R = Hydraulic radius, feet
S = Slope ratio
n = Manning's roughness coefficient

V = Velocity, feet/second

B. Materials

All underground storm drains shall comply with the material requirements of the AHJ and unless otherwise specified, shall be reinforced concrete pipe (RCP). RCP located in track rights-of-way shall be provided with cathodic protection as necessary. High-density polyethylene pipe may be used where its use is approved by the AHJ. Drain connections in structural walls and floors shall be ductile iron pipe.

C. Manning's Roughness Coefficient shall be in accordance with the requirements of the AHJ.

D. Structural Considerations

Class of pipe and bedding shall be determined from foundation conditions, depth of cover, and loading conditions.

6.3.6.2 Open Channel

A. For open channel design, the Manning formula shall be used.

B. Materials and Manning's Roughness Coefficient shall be in accordance with the requirements of the AHJ.

Material	Manning “n”	Maximum Velocity (feet/second)
Concrete	0.013-0.015	19
Sod on clay soil	0.025	8
Sod on clay and sand mix	0.025	6
Sod on sandy soil	0.030	4

6.3.7 Flood Control

The design of the transit system shall include an analysis of the potential for flooding in the vicinity of transit facilities. The analysis shall consider such flood sources as storm surge flooding of streams, flood control channels, storm drainage systems, and surface flows. The Designer shall perform the analysis early in the design and submit the analysis, together with recommendations for protecting the transit facilities from flooding, to the RTD for approval. Proposed protection shall address all openings into the transit facilities, including station entrances, vent shafts, emergency exits, access hatches, and utility connections.

6.4 SITE WORK AND PARKING FACILITIES

6.4.1 General

A. This sub-section establishes criteria and standards for the design of private streets, parking lots, parking structures, pedestrian facilities, and driveways, all of which are to be maintained for the duration of the Project. Justification for access locations and additional lane requirements should be based on the project traffic analysis report.

For additional design criteria guidelines relating to site work and parking facilities, refer to Chapter 7, Traffic and Chapter 10, Architecture.

B. Basic Goals

1. To provide for the safety of transit patrons while arriving, waiting at, or departing from the station site.
2. To establish convenient traffic circulation patterns for vehicular and pedestrian movement.
3. To provide parking facilities which are safe, convenient, attractive, and easily maintained.

6.4.2 Site Access

6.4.2.1 Patrons will arrive at and depart from stations in as many as 10 basic modes as follows:

1. Pedestrian
2. TheBus

3. Park-and-ride
4. Kiss-and-ride
5. TheHandi-Van
6. Taxis
7. Private shuttle
8. Private tour bus
9. Motorcycle
10. Bicycle

6.4.2.2 Site Elements

A. Pedestrian Access

1. Pedestrian crosswalks should be emphasized with a strongly contrasting change in paving material, surface texture, or color and should be well lit.
2. Parking areas should be arranged to minimize the number of pedestrian/vehicular conflicts.
3. Isolated and remote or hidden pedestrian walkways should be avoided. Where avoidance is not feasible, they should be as open as possible and well lit.
4. The effective width of exterior pedestrian walkways is the total walkway width minus obstacles such as parking meters, poles, fire hydrants, trash cans, etc. An additional 1-foot per side should be subtracted due to the tendency of people to avoid walking close to walls or barriers.
5. Pedestrian walkways should have a continuing common surface, not interrupted by steps or abrupt changes in level.

B. Bicycle Access

1. Wherever possible, bicycle paths or lanes (in street) shall be provided as an integral part of the site work.

C. Vehicular Access

Vehicular entrances to station sites shall be in accordance with the following:

1. Locations of Vehicular Access points shall follow proper access management techniques.

2. Vehicular entrances from public streets shall be from minor streets where possible, with provisions for sufficient stacking space provided at intersections with major streets.

3. Separate access points into the site from the same street should be at least 150 feet apart.

4. Entrances, where feasible, should be so located that a vehicle approaching the station from any direction, missing one entrance, will find a second available without circuitous routing.

5. Wherever the volume of traffic entering or exiting a public street increases the street traffic volume beyond the street capacity, the addition of auxiliary lanes shall be considered.

6. Separation of vehicular modes of access shall be provided whenever possible due to the differing circulation needs and priorities assigned to TheHandi-Vans, TheBuses, kiss-and-ride, and park-and-ride.

6.4.3 Parking Facilities

6.4.3.1 Parking Facility Elements

A. Parking Lanes and Curb Loading Zones

B. Placement of loading zones on access roadways shall reflect the following order of preference with respect to proximity of the loading zone to the station concourse:

1. TheBus
2. TheHandi-Van
3. Kiss-and-ride
4. Taxis
5. Private shuttle
6. Private tour bus
7. Bicycle
8. Motorcycle
9. Park-and-ride

C. On site parking along project roadways preferably shall be parallel to the curb. Lane width prescribed herein for parking and loading zones includes the gutter width.

D. Individual stations will have different capacity requirements for the various loading zones. Refer to the “Station Area Transportation Access Mode Space Requirements” matrix for capacity at each specific station.

E. Loading zones for shall be located to provide the most direct and safest intermodal transfer.

6.4.3.2 TheBus, TheHandi-Van, and Taxis

A. The required bus (or taxi) design capacity for a station shall be determined by the RTD based on the individual requirements for each station.

B. The standard layout for various types of bus loading zones shall be designed in accordance with the standards and requirements of the appropriate agency having jurisdiction.

C. Bus lanes shall be one-way only through the station site and preferably configured in a counter-clockwise orientation.

D. Bus lanes shall be designed to allow buses in motion to pass parked and stalled buses.

E. Bus layover provisions should be configured to allow buses to layover and then move up to their assigned spaces for boarding.

F. Where possible, it is desirable for buses to be able to re-circulate within the off-street station site.

G. Sawtooth bus bays may be used in off-street bus terminals only.

H. Bus bays shall be designed to allow loading and unloading of passengers from the right side of the bus to pedestrian paths.

I. Bus bays will be oriented so that bus patrons do not need to cross traffic to reach the station entrance.

6.4.3.3 Kiss-and-Ride Facilities

A. The required design capacity for a station shall be determined by the RTD based on the individual requirements of each station.

B. Kiss-and-ride facilities are preferred to be located off-street, as near to the main station entrance as practical, and shall be physically separate from long-term parking areas and park-and-ride facilities. The location should, if possible, be such that a driver can view the station entrance to see an exiting passenger for whom he is waiting.

C. A parking area for persons waiting to pick up handicapped persons shall be provided as required by installing appropriate pavement markings and signs.

D. All kiss-and-ride parking spaces shall be delineated by signs and curb markings as being limited to short-term use.

E. Kiss-and-ride parking stalls shall be 9 feet wide and preferably at a 60-degree angle and will be pull-through, if possible.

F. Kiss-and-ride is primarily a suburban transit station activity associated with transit stations, one which includes drop-off, pick-up, and short-term parking functions. Pedestrian safety and security is of the highest priority in the design of these facilities.

G. In more densely populated areas, where off-street kiss-and-ride facilities are not provided or spaces are not of sufficient number, consideration should be given to the addition of vehicular lanes on local roadways adjacent to the stations to lessen the impact of the drop-off/pick-up activities that will naturally occur.

H. Convenience, safety, and appropriateness to the overall site and neighborhood are prime design objectives.

I. Access roads shall be single lane, yet allow space to maneuver around a stopped vehicle.

J. When possible, the kiss-and-ride vehicle should be able to re-circulate on-site in the event a space is not available.

K. Site constraints will dictate whether drive-through or dead-end spaces are provided.

L. Where the taxi queue is part of a kiss-and-ride facility, the queue shall be located along the curb line near the station entrance with the first space situated at a natural point of concentration of pedestrian traffic from that station entrance.

M. Drop off zones should be incorporated into the kiss-and-ride areas to promote better peak services. Drop off zones should also be provided for taxis when the use of kiss-and-ride drop off zones are not allowed.

6.4.3.4 Park-and-Ride Facilities

The required design capacity for a station shall be determined by RTD based on the individual requirements of each station.

6.4.3.5 Private Shuttle and Tour Bus Facilities

A. The required design capacity for a station shall be determined by RTD based on the individual requirements of each station.

B. The private shuttle and tour bus facilities shall be located off-street, as near to the main station entrance as practical, and shall be physically separate from long-term parking areas and bus-and-ride facilities. Loading shall be from the right-hand side of the vehicle. The location should, if possible, be such that a transit rider can view the waiting shuttle or tour bus from the station entrance.

C. All private shuttle and tour bus facility parking spaces shall be delineated by signs and curb markings as being limited to short-term use.

D. Private shuttle and tour bus parking stalls shall be a minimum 9 feet wide and preferably at a 60-degree angle.

6.4.3.6 Motorcycle Parking

There shall be a minimum total number of 10 motorcycle parking spaces at a station. Motorcycle parking shall be placed at the park-and-ride facility entrance where public visual surveillance is possible and/or where CCTV monitoring is present.

6.4.3.7 Bicycle Facilities

A. Provision shall be made for access to and from stations by bicycle, including their storage at station sites.

B. The required design capacity for a station shall be determined by RTD based on the individual requirements of each station.

C. Bicycle racks shall be placed at the station plaza near the station entrance where public visual surveillance is possible and/or where closed-circuit television (CCTV) monitoring is present.

6.4.3.8 Parking Stalls

A. Disabled parking spaces shall be located as near as practical to a primary entrance to a facility (building, station entrance, or boarding platform). The space shall be located so that a handicapped person does not have to wheel or walk behind parked cars other than his/her own. Pedestrian ways shall provide an accessible pathway from each such parking space to the facility.

6.4.3.9 At-Grade Parking

A. Where access roadways have a combined usage, with bus and car traffic being mixed, the station site entrance and exit conditions shall be delineated by the Designer to minimize turning movements against on-coming traffic.

B. Park-and-ride facilities should be sited to avoid adverse impact to the community it serves. The site design should respect the existing topographic conditions, including existing natural vegetation, with the goal of minimizing destruction of the existing natural conditions.

C. Park-and-ride facilities shall be designed with 90-degree angle parking (preferred), two-way circulation, and a minimum of dead-end parking areas. If restricted by right of way or some other constraint, 45 and 60-degree parking can be considered.

D. Park-and-ride facilities shall be designed utilizing sustainable design best practices as set forth by the U.S. Green Building Council as described in their Leadership in Energy and Environmental Design standards and rating system. Reduced site disturbance, innovative stormwater management design, reduction of heat islands, provision for on-site rainwater retention, and the use of permeable paving materials are but a few examples.

E. Large parking lots shall be subdivided into sections no larger than 500 cars to reduce their scale. Landscape buffers with 50 feet as their desirable width shall be used for this purpose. However, vehicular movement from each section to the next shall not be restricted.

F. Park-and-ride lot landscape design shall complement sight lines to the station entrance(s) as well as enabling good surveillance of the entire lot.

G. Landscape requirements for parking lots shall comply with the requirements of the local codes and zoning regulations. Continuous 10-foot-wide (preferred minimum) landscaping areas shall be located every second parking bay and be designed as an integral part of the on-site rainwater detention system.

H. Pedestrian circulation and sidewalk inclusion will not supplant the landscape areas required by the local codes and regulations.

I. Compact car spaces shall be provided in accordance with local zoning requirements.

J. Parking space row driving aisles shall be oriented toward the station entrance enabling visual connections to the entrance and walking in the driving aisles, thereby shortening pedestrian walking distances. Collector sidewalks leading to the station shall be oriented perpendicular to the driving aisles and sized to accommodate the volumes they serve.

K. Where site stairways are required, they shall be the same width as the adjoining sidewalks and have 14-inch (minimum) treads and 6-inch (maximum) risers with continuous handrails on both sides.

6.4.4 General Site Work And Parking Facility Elements

6.4.4.1 Traffic Lanes

All on site roadways serving the parking facilities, other than those used mainly for service or maintenance purposes, shall have at least one traffic lane for each direction of travel. The number of traffic lanes provided on these roadways shall be sufficient so that the vehicular volume per lane does not exceed 300 vehicles per hour.

6.4.4.2 General Design Elements

A. Design Vehicle

The criteria relating to the Single Unit (SU) vehicle stalls shall be based on the specifications and design guidelines of the local agency responsible for local parking lot layout.

B. Design Speed

The design speed for this section varies as follows:

1. Parking Facilities: Not applicable
2. Yard Site Facilities: 20 mph

6.4.4.3 Cross Sectional Elements

A. On Site Lane Widths

The following criteria indicate maximum, minimum, and desirable values for traffic lane widths. In cases of significant constraint, a width reduction may be necessary.

1. Through lanes (Two-way)(multiple): 12 feet preferred, 11 feet minimum
2. Through lane (One-way)(single): 20 feet preferred
3. The following criteria indicate maximum, minimum, and desirable values for on site bus bay dimensions:

Bus Bay	Type/Location	Dimension
Tangent bus bay	Standard	10 feet x 50 feet + taper
	Articulated	10 feet x 70 feet + taper
Tapers	Entry	1:5 minimum
	Exit	1:3 minimum
Saw tooth bus bay	Standard	62 feet with 7-foot-6-inch indent
	Articulated	85 feet with 7-foot-6-inch indent
Storage bay (layover)	Standard	10 feet x 50 feet + taper
	Articulated	10 feet x 70 feet + taper
TheHandi-Van	Standard	10 feet x 25 feet + taper

B. On Site Parking Lanes

The following criteria indicate maximum, minimum, and desirable values for on site parking stall dimensions:

Spaces	Dimensional Criteria
Drop-off spaces	9 feet x 18 feet
Private Shuttle /	On Street - 10 feet desired width; 9 feet minimum
Tour Bus	Angled - 60° 10 feet width
Motorcycle	4 feet x 8 feet; signage indicating parking spaces are for two-wheel cycles only
Elderly and disabled	Accessible spaces shall comply with ADA Accessibility Guidelines regulations and any local codes whose requirements may be more stringent.

Stall Type	Stall Angle			
	Parallel	45°	60°	90°
Design Vehicle: SU				
Standard and Handicapped (per ADA Standards)				
Width (feet) (min)	8	8.5	8.5	8.5
Length (feet) (min)	22	25	22	18
Clear aisle width – One-way (feet)		13	19	N/A
Clear aisle width – Two-way (feet)		N/A	N/A	24
Handicapped Access aisle (feet)		5	5	5

C. Parking Stalls

When parking is provided for patrons, employees, or visitors, the minimum number of handicapped spaces required is as follows:

Total Number of Parking Spaces	Number of Disabled Parking Spaces Required
1 to 25	1
26 to 50	2
51 to 75	3
76 to 100	4
101 to 150	5
151 to 200	6
201 to 300	7
301 to 400	8
401 to 500	9
501 to 1,000	2 percent of total
1,001 and over	20 plus 1 for each 100 over 1,000

D. Cross Slope

1. Cross-slope 2 percent

E. Horizontal Clearance

F. Vertical Clearance

1. Parking Facilities

a. Vertical: 7 feet

b. Horizontal: 30 inches

G. Side Slopes

Cut-and-fill-slopes shall be as flat as possible and shall not exceed a slope of 1:2 (vertical to horizontal) or as recommended by the Designer's geotechnical consultant. Tops of cut slopes shall be rounded.

H. Drainage

Drainage design shall include the following:

1. Surfaces shall be sloped to drain away from areas where pedestrians walk.
2. Catch basins shall not be located in pedestrian walkways.

I. Sidewalks

1. No pedestrian ramp should have a slope greater than 5 percent.
2. The width of on site pedestrian walkways shall be as follows:

On Site Pedestrian Walkways	Preferred Width (feet)	Minimum Width (feet)
Walkways through bus stop areas	12	8
Walkways adjacent to long-term parallel parking	8	6
Walkways adjacent to short-term parallel parking	10	8
Crosswalks	15	10

6.4.4.4 Horizontal Geometric Elements

A. Elements Site Distance

B. Curb Return Radius

1. Parking Facilities

   a. For taxis: 19.5 feet (inside radius)

   b. For buses: 30 feet minimum (inside radius), 49 feet minimum (outside radius clear)

   c. For passenger cars: 15 feet minimum (inside radius), 26 feet minimum (outside radius clear)

6.4.4.5 Vertical Geometric Elements

A. Vertical Geometry

1. Parking Facilities

   a. Parking Lot: 5 Percent (Maximum), 0.5 Percent (Minimum)

2. On Site Roadways

   a. On Site Roadway: 6 Percent (Maximum), 0.5 Percent (Minimum)

B. Vertical Curves

1. On Site Roadways

Vertical curves shall be not less than 65 feet

   a. Crest Curves: L_{min} = 28 A

   b. Sag Curves: L_{min} = 36 A

   where: L_{min} = Minimum vertical curve length, feet
   A = Algebraic difference in grades, percent

C. Algebraic Difference in Grade

1. On Site Roadways

Crest and sag curves at top and bottom of ramps without parking may exceed these differentials but must use a vertical curve 200 feet in length or more.

   a. Crest vertical curve: 9 Percent (Maximum)

   b. Sag vertical curve: 6.5 Percent (Maximum)

END OF CHAPTER

Honolulu High-Capacity Transit Corridor Project

(Project)

DESIGN CRITERIA

CHAPTER 7

TRAFFIC

April 3, 2009

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7.0 TRAFFIC

7.1 GENERAL

7.1.1 Introduction

This Chapter establishes the basis for engineering criteria and the related work to be used in the design of the Project and

- Includes requirements for traffic control devices and criteria for the design of traffic signal systems, signing, and pavement markings as they apply to interfacing the Project with the street and highway network along the alignment.
- Describes the criteria to be used for signs and pavement markings, curb markings in streets, parking lots, and parking structures.
- The criteria should be used collectively to meet the requirements of specifications and design guidelines in accordance with the current practices of the State, County, and Local jurisdictions in which the Project will be constructed.

The Designer shall use all available traffic data and the design standards in coordination with any roadway, traffic signal, or other traffic improvements.

7.1.2 Reference Data

The traffic-related design elements of the Project shall comply with the Local agency having jurisdiction and the applicable standards, manuals, policies, codes, regulations, plans, documents, and specifications listed below:

A. American Association of State Highway and Transportation Officials. *Roadside design guide.*

B. American Association of State Highway and Transportation Officials. *A policy on geometric design of highways and streets.*

C. American Association of State Highway and Transportation Officials. *Standard specifications for structural supports for highway signs, luminaries and traffic signals,* including modifications contained in HDOT's *Design criteria for bridges and structures.*

D. City and County of Honolulu Department of Transportation Services. *Traffic code.*

E. City and County of Honolulu, County of Kauai, County of Maui, County of Hawaii, State of Hawaii. *Standard details for public works construction.*

F. City and County of Honolulu. *Standard specifications.*

G. City and County of Honolulu. *Traffic design manual.*

H. City and County of Honolulu. *Traffic standards manual.*

I. Federal Highway Administration. *Manual on uniform traffic control devices for streets and highways.*

J. Federal Register. *ADA accessibility guidelines for buildings and facilities (ADAAG).*

K. National Electrical Manufacturers Association

L. National Transportation Communications for ITS Protocol

M. State of Hawaii Department of Transportation. *Standard plans.*

N. State of Hawaii Department of Transportation. *Standard specifications for road, bridge, & public works construction manual.*

Unless specifically noted otherwise herein, the latest edition, or as administered by CCH, of the code, regulation, standard, and standard plan that is applicable at the time the design is initiated shall be used. If a new edition or amendment to a code, regulation, standard, or standard plan is issued before the design is completed, the design shall conform to the new requirements to the extent practical or required by the governmental agency enforcing the code, regulation, standard, or standard plan changed.

7.2 MAINTENANCE OF TRAFFIC

A. The Designer shall prepare Maintenance of Traffic (MOT) Plans which include detour routes, alternate routes, haul routes, and street and sidewalk closures. The MOT plans shall provide safe and continuous passage to local pedestrians and vehicular traffic and allow for the safe construction of the facility at all times.

B. The Designer shall coordinate and interface, as appropriate, with the MOT plans of adjacent project contracts and other projects. The Designer's MOT plans shall include the necessary traffic staging, phasing, detours, details, signing, and marking as well as any additional plan sheets necessary to ensure proper MOT through and around the construction site and any appropriate mitigation measures. The MOT plans shall be submitted to the State of Hawaii Department of Transportation (HDOT), and/or the City and County of Honolulu (City) for review and approval.

C. For major roadways, including divided highways, lane closures shall be limited to a maximum width of one lane at a time whenever possible. This restriction allows remaining lanes, in both directions, to be maintained for motorists. Lane closures shall be approved by HDOT and the City prior to any closure.

D. The Designer shall develop the MOT plans such that the time of street closures will minimize impacts on traffic and pedestrian thoroughfare. Hours of operation shall be approved by HDOT and the City prior to any closure.

E. Emergency, local, pedestrian and Safe Routes to School access shall be maintained at all times.

F. Maintenance of bus routes—Private, public, and school bus routes, which travel through the project limits of construction, have the potential for disruptions in their routes. Proposed temporary relocation of terminals/stops and rerouting shall be prepared by the Designer and submitted to the TheBus and the affected entity for review, approval, and coordination.

7.3 TRAFFIC CONTROL DEVICES

7.3.1 General

The following describes the criteria to be used for temporary and permanent traffic control devices in streets, parking lots, and parking structures.

The application of any traffic control device shall:

A. Fulfill an important need

B. Be located in such a manner as to command attention and provide adequate time for response

C. Command respect and gain compliance

D. Convey a clear, simple, and appropriate message

E. Complement a good design

7.3.2 Signing

A. Signs shall be displayed only for the specific purpose and under the specific conditions prescribed in these criteria.

B. Signs shall not be used to confirm well known or universally recognized rules of the road. Signs shall be used where special regulations apply at specific places or at specific times only or where hazards are not self-evident. Care shall be taken not to install too many signs, especially those of the regulatory or warning types, which, if used in excess, tend to lose effectiveness.

C. Installation of temporary signs shall be coordinated with HDOT and/or the City.

D. The Designer shall coordinate with HDOT and/or the City for compatibility of street signing with the project construction staging plans.

E. Various institutions and facilities located in and around the project limits of construction generate vehicular and pedestrian traffic. Many of these traffic generators will need special consideration in planning and scheduling for MOT, such as hours of operation, access, and detours which shall comply with general guidelines of the Maintenance of Traffic section of these criteria. Special vehicle and pedestrian generators include, but are not limited to, the following:

   1. Schools
   2. Hospitals
   3. Parks, playgrounds, and ball fields
   4. Shopping centers/malls

5. Fire and police stations

6. Government centers

F. Messages used for portable Dynamic Message Signs (DMS) shall follow a consistent format. Coordinate message formats including abbreviations, typical message layout, number of screens per message, and flash rate with HDOT and the City.

7.3.3 Striping

Paint materials; striping details, including standard pavement marking; striping with markers; striping transitions; and crosswalk detail are to be obtained from standard plans and drawings of each jurisdiction where appropriate and shall comply with current Americans with Disabilities Act criteria.

END OF CHAPTER

Honolulu High-Capacity Transit Corridor Project

(Project)

DESIGN CRITERIA

CHAPTER 8

UTILITIES

April 3, 2009

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8.0 UTILITIES

8.1 GENERAL

These procedures and design criteria shall govern all new utility construction outside of buildings, and the support, maintenance, relocation, and restoration of utilities encountered or affected by the transit system construction. Attention shall be given to the needs of the transit system, the requirements and obligations of the public and private utility owners, and the utility service needs of adjacent properties.

8.1.1 Goals

This chapter of the criteria deals with the utilities that are impacted by the Project, whether the utility needs to be temporarily or permanently protected and/or temporarily or permanently relocated.

The criteria relating to other elements of design and to work items necessitated by the transit system construction, such as miscellaneous utility work, roads/paving, grading, drainage, fencing, and surveying/mapping, are based on the current specifications and practices of the concerned government agencies.

8.1.2 Reference Data

The utilities identified herein each have specific codes and standards that must be followed. As such, codes and standards are listed within the utility subsection.

8.2 UTILITIES

8.2.1 General

A. These criteria govern the maintenance, support, restoration, and relocation of utilities encountered or affected by the construction of the transit system. In the performance of work, due consideration shall be given to the needs of the transit system, the requirements and obligations of the utility owners, the traffic requirements, and the cooperative agreements between the utility agencies or companies and the City and County of Honolulu, Department of Transportation Services, Rapid Transit Division (RTD).

B. Utilities comprise facilities owned by public utility agencies and private utility companies and include service lines to adjoining properties.

1. Public utility agencies include, but are not limited to:
    a. City and County of Honolulu (CCH)
        i. Board of Water Supply (BWS)
        ii. Department of Design and Construction (DDC)
        iii. Department of Parks and Recreation (DPR)
        iv. Department of Environmental Services (ENV)

v. Department of Facility Maintenance (DFM)

vi. Department of Transportation Services (DTS)

vii. Department of Planning and Permitting (DPP)

(a) Site Development Division (DPP-SDD)

(i) Civil Engineering Branch (DPP-CEB)

(ii) Wastewater Branch (DPP-WB)

(iii) Subdivision Branch (DPP-SB)

(iv) Traffic Review Branch (DPP-TRB)

b. State of Hawaii

i. Department of Accounting and General Services (DAGS)

ii. Department of Land and Natural Resources (DLNR)

iii. Department of Transportation (HDOT)

(a) Highway Division (HDOT-HWY)

(b) Airport Division (HDOT-AIR)

(c) Harbor Division (HDOT-HAR)

c. Department of Defense (DOD)

i. Department of Navy

ii. Department of Army

iii. Department of Air Force

2. Private utility companies include, but not limited to:

a. Hawaiian Electric Company, Inc. (HECO)

b. Hawaiian Telcom, Inc.

c. Oceanic Time Warner Cable (OTWC)

d. The Gas Company (TGC)

e. AT&T Corporation (AT&T)

f. Sandwich Isles Communications, Inc. (SIC)

g. TW Telecom, Inc. (TWTC)

h. Pacific LightNet, Inc. (PLNI)

i. Chevron Products Company

j. Tesoro Hawai'i Corporation

C. Utilities encountered or close enough to be affected by the transit construction may be

1. Supported and maintained complete in place during construction and continued in service following completion of the transit facilities.

2. Temporarily relocated during construction; then, upon completion of the transit facilities, restored to service.

3. Temporarily relocated and maintained; upon completion of the transit facilities, replaced by new utilities.

4. Permanently relocated beyond the immediate limits of transit construction.

D. Utility service to abutting properties shall not be interrupted and, if temporarily relocated, the temporary facilities will be removed and the area restored as close as possible to its original condition or better.

E. Replacements of and pavements for any existing utilities shall be designed to provide service or capacity equal to that offered by the existing installations. The Designer shall comply with local codes and standards of the agencies having jurisdiction.

Unless specifically noted otherwise herein, the latest edition or as administered by the City and County of Honolulu (CCH) of the code, regulation, standard, and standard plan that is applicable at the time the design is initiated shall be used. If a new edition or amendment or as administered by CCH to a code, regulation, standard, or standard plan is issued before the design is completed, the Designer shall determine the impact of the change and seek for RTD's direction on how to proceed.

F. Improvements to utilities shall not be included unless specifically approved by RTD.

G. All designs involving maintenance, support, and relocation or other utility work shall conform to the applicable specifications, criteria, and standards of and be approved by the utility owner.

H. Record elevations of all utilities shall be adjusted to project datum. Pertinent utility elevations and locations shall be checked by field survey and, where critical to design, by digging test holes at locations accepted by RTD.

I. The Designer shall consider plans developed, or being developed, by others in adjoining sections to ensure that the overall utility systems will be consistent with those existing before the start of construction, and that the systems will be compatible with those of the transit system.

J. Design of utility rearrangements shall ensure that construction of the transit facilities may proceed without undue hindrance and without affecting the continuity of utility service. The design shall consider space requirements for equipment and materials and clearances for installation of temporary traffic decking. When the Designer indicates temporary deck structures on the plans, allowable clearances of affected utilities should be considered.

K. The Designer shall take into account the needs of each utility for maintenance and accessibility while designing horizontal and vertical alignments. Separation between utilities shall be per utility design requirements and standards, whichever is more stringent.

L. Where utilities cross under or run parallel to rail alignments, live loads imposed by transit facilities in design of utility and utility casings shall be considered. Protection of both the utility and the transit facility must be considered.

M. Utilities which penetrate through or cross over transit structures shall be designed to prevent shear failure and shall be encased, if necessary, to prevent damage.

N. During the design period, the Designer shall maintain continuous communication and coordination with the affected utility agencies and companies as well as CCH and HDOT to achieve the following:

1. Supply the utility agencies and companies with preliminary plans and specifications and request verification of existing facility sizes and locations.
2. Coordinate with and request the utility agencies and companies to develop temporary or permanent relocation plans of their facilities. Also, request a cost proposal for the work.
3. The Designer and RTD shall review the relocation plans supplied by the utility agencies and companies, and the Designer shall then develop an independent quantity and/or cost estimate for the work.
4. Final engineering design for utilities will be completed by the Designer or respective utility agencies or companies. Plans prepared for utilities by others shall be reviewed and approved by the respective utility agencies or companies. Plans prepared by a utility agency or company shall be reviewed and approved by the Designer, RTD, and/or HDOT.
5. All utility works, either constructed by others or the Contractor, shall be shown on the plans. If the work is to be constructed by others, it should be so indicated on the plans.

O. Utility markers will be placed if so required by the utility agency or company. For hazardous liquid pipeline, one-call markers must be placed.

8.2.2 Sanitary Sewers (ENV and DPP-WB)

8.2.2.1 Codes and Standards

All maintenance, relocation, restoration, and construction of sewer facilities shall conform to the current design standards and criteria, specifications, and practices of ENV and DPP-WB, including

A. City and County of Honolulu Department of Wastewater Management. July 1993. *Design Standards of the Department of Wastewater Management, Volume I.*

B. City and County of Honolulu Department of Public Works. September 1984. *Standard Details for Public Works Construction.*

C. City and County of Honolulu Department of Public Works. September 1986. *Standard Specifications for Public Works Construction.*

Design and construction of sanitary sewer laterals to abutting properties shall conform to applicable ENV and DPP-WB standards and codes.

8.2.2.2 General

A. Sanitary sewer mains and service laterals to adjoining properties shall be maintained by supporting in place, providing alternative temporary facilities, or diverting to other points.

B. Temporary sanitary sewer piping systems shall be of adequate size and slope to handle the flows of those sewers taken out of service. No sanitary sewage shall be discharged onto transit facilities, public streets, or public/private rights-of-way.

C. All temporary sanitary sewer facilities provided by the Contractor during construction shall be removed and replaced with new permanent facilities.

D. Capacity and service of replacement sanitary sewer system shall be equivalent to existing system and shall meet or exceed the latest design standards, based on the published design requirements of ENV and DPP-WB.

E. Conduits shall be designed to maintain minimum velocities at minimum design flow and not exceed a depth of flow at peak design flows according to ENV and DPP-WB standards.

F. Separation between sanitary sewers and water lines shall be per utility design requirements and ENV and DPP-WB standards. In general, water lines shall be above the sewer lines.

G. The Designer shall review site specific conditions, including flow capacity of existing sanitary sewers affected by transit facilities, and incorporate such modifications into the relocation or realignment plans to protect both the utility and transit facilities.

8.2.3 Storm Drains (DPP-CEB and HDOT-HWY)

8.2.3.1 Codes and Standards

All maintenance, relocation, restoration, and construction of drainage facilities shall conform to the current design standards and criteria, specifications, and practices of DPP-CEB and HDOT-HWY, including

A. City and County of Honolulu Department of Planning and Permitting. January 2000. *Rules Relating to Storm Drainage Standards.*

B. City and County of Honolulu Department of Planning and Permitting. April 1999. *Rules Relating to Soil Erosion Standards and Guidelines.*

C. City and County of Honolulu Department of Public Works. September 1986. *Standard Specifications for Public Works Construction.*

D. City and County of Honolulu Department of Public Works. September 1984. *Standard Details for Public Works Construction.*

E. State of Hawaii Department of Transportation Highway Division. 2008. *Standard Plans.*

8.2.3.2 General

A. Existing storm drain facilities shall be maintained by supporting in place, if conveyance system is water tight, providing alternative temporary or permanent facilities, or diverting flows to other points. Unless approved by respective utility owners, existing pipe conduits shall not be supported and reburied.

B. All temporary storm drainage facilities used during construction shall be removed and restored with new permanent facilities. Restored facilities shall have capacities equivalent to those of existing.

C. Area drainage conditions for local flooding shall be reviewed and incorporated into design of storm drain facilities to provide for protection of transit facilities.

D. No catch basins, utility drains, or subsurface drains shall be connected to sanitary sewers.

E. New pipe conduits shall have rubber gasket joints where they cross the transit facilities.

F. No surface drains from adjoining areas shall be connected to the transit drainage system.

G. New drainage facilities shall be designed in accordance with criteria established in Chapter 6, Civil.

8.2.4 Water (BWS)

8.2.4.1 Codes and Standards

A. All maintenance, support relocation, restoration, and construction of water mains and appurtenances shall conform to current design standards and criteria, specifications and practices of BWS, including Water System Standards, Board of Water Supply, City and County of Honolulu, State of Hawaii, 2002.

B. Construction of water services to abutting properties shall conform to applicable BWS standards and codes.

8.2.4.2 General

A. Replacement of existing water mains and appurtenances shall provide capacities and services equivalent to those provided by the replaced facilities.

B. Services to adjoining properties shall be maintained by supporting in place, providing alternative temporary facilities, or diverting from other points.

C. Upon approval from BWS, water lines through cut-and-cover construction shall be supported in place and braced to resist internal and external forces. New lines shall be aligned such that further relocation for placement of temporary decking or station construction will not be required.

D. Where major water distribution facilities cross an at-grade section of the project alignment, installation of emergency isolation valves outside the construction site shall be considered if suitable isolation valves do not presently exist. Location and type of valve shall comply with criteria and requirements of BWS. These water distribution facilities shall be encased, as needed, and per BWS requirements.

E. Cathodic protection shall be provided in accordance with Chapter 17, Corrosion Control.

F. New water system materials shall comply with criteria and requirements of BWS.

8.2.5 Gas (The Gas Company)

8.2.5.1 Codes and Standards

All work on, or adjacent to, gas lines shall conform to the latest regulations, the design standards, and specifications of The Gas Company (TGC).

8.2.5.2 General

A. The Designer shall inform TGC if and where the transit system will affect TGC's gas mains.

B. Removal, installation, and connection of temporary or permanent gas mains shall be performed by TGC.

C. The work to be done by TGC shall be indicated in the plans.

D. Where possible, new gas lines shall be placed within the street, parkway, or in the curbside lane 12 inches from the lip of the gutter.

E. With the exception of a minimum of 24 inches of clearance for 16 inches gas transmission line, a minimum of 12 inches of vertical or horizontal clearance between the gas lines and other utilities, or other facilities shall be maintained unless the other utility has a more stringent requirement.

8.2.6 Electric Power (Hawaiian Electric Company)

8.2.6.1 Codes and Standards

All maintenance, relocation, and restoration of electric lines throughout the transit system shall conform to the latest design criteria and standard specifications of HECO, Chapter 6-73 of Hawaii Administrative Rules (HAR 6-73), and the requirements of the National Electrical Code (NEC) and the National Electrical Safety Code (NESC).

8.2.6.2 General

A. The preparation of designs shall be coordinated with and conform to design requirements of HECO and coordinated with any other concerned governmental agencies.

B. Work to be done by HECO shall be indicated in the plans. HECO will install and energize all cables, make conduit connections to existing vaults, connect and energize all services, and de-energize and remove cables from all facilities to be abandoned. HECO will de-energize and energize the power lines.

C. Plans shall show all existing overhead and underground power lines and indicate those required to be abandoned or relocated. The clearances of overhead and underground power lines shall comply with the rules and regulations of HECO and HAR 6-73. The final design shall be approved by HECO.

D. Existing conduits and vaults within the work area shall be supported in place where possible. When facilities must be relocated, the plans shall indicate alignment and depths such that future relocation to facilitate construction will not be necessary.

E. All ducts and vaults to be abandoned and removed shall be identified.

F. All HECO conduits installed by the Contractor shall be encased according to HECO standards.

G. Vertical and lateral clearances from transit facilities to overhead lines shall comply with HECO requirements, HAR 6-73, or NESC requirements, whichever is more stringent.

8.2.7 Telephone (Hawaiian Telcom)

8.2.7.1 Codes and Standards

All maintenance, relocation, and restoration of telephone lines throughout the transit system shall conform to the latest design criteria and standard specifications of Hawaiian Telcom, HAR 6-73, and the requirements of the NEC and the NESC.

8.2.7.2 General

A. Where possible, existing cable ducts and vaults will be supported in place or moved in such manner to avoid cutting the cables.

B. The plans shall indicate which telephone lines are to be maintained complete in place; which ducts are to be removed, cables supported temporarily during work and, upon completion of work, replaced by a new system of ducts and cables; and any rerouting or new construction. Abandoned lines, and those to be abandoned, shall also be indicated.

C. The plans shall indicate which work, primarily pulling and cutting-over new cables, will be performed by Hawaiian Telcom or its representative.

D. Telephone lines maintained or installed within limits of transit system excavation shall require permanent support.

E. Preparation of the plans shall be coordinated with Hawaiian Telcom.

F. The design for lowering of cables will be coordinated with other utility work to eliminate the need to cut and splice telephone cables.

G. Minimum depth of conduits shall be in accordance with the requirements of Hawaiian Telcom and HAR 6-73.

H. Installation of temporary and permanent manholes, split case ducts, and duct encasement shall conform to Hawaiian Telcom standards and practices.

I. Vertical and lateral clearances from transit facilities to overhead telephone and other communication lines shall comply with Hawaiian Telcom requirements, HAR 6-73, or NESC requirements, whichever is more stringent.

8.2.8 Miscellaneous Telecommunications

In the event of design involving maintenance, relocation, or restoration of communications cables other than telephone, such as cables owned by Oceanic Time Warner Cable, AT&T Corporation, National Defense Cables, and other private telecommunications systems, the Designer shall verify ownership and, after consultation with the owners, coordinate the necessary design work in accordance with the codes and standards of the companies and agencies affected.

8.2.9 Parks (DPR)

8.2.9.1 Codes and Standards

Relocation and restoration of underground utility lines, water mains, sewers, drains, catch basins, sprinkler systems, lights, pavements, and other improvements within parks shall conform to requirements of DPR.

8.2.9.2 General

The design for the various facilities shall be submitted to DPR for approval.

8.2.10 Street Lights (DDC-MED and HDOT-HWY)

These criteria refer to removal and restoration of existing street lighting facilities.

8.2.10.1 Codes, Regulations, and Standards

All relocation, temporary or permanent, and restoration of existing street light facilities shall be in accordance with the practices and requirements of HECO and local electrical codes, including the City and County of Honolulu, Department of Design and Construction, Mechanical/Electrical Division (DDC-MED), the State of Hawaii, Department of Transportation, Highway Division (HDOT-HWY), and the NESC.

8.2.10.2 General

A. Street light design shall conform to local electric codes and requirements, HECO electrical code, and the NESC.

B. The Designer shall coordinate the design work with the DDC-MED, HDOT-HWY, and the affected agencies for jurisdictional compliance.

C. Materials, spacing, height, and conduit depth shall be in accordance with the requirements of DDC-MED, HDOT-HWY, and other affected agencies.

8.2.11 Traffic Signals (DTS)

A. These criteria refer only to relocation and restoration of existing traffic signals and construction of temporary traffic signals within public rights-of-way. Refer to Chapter 6, Civil, and Chapter 7, Traffic, with respect to new installations.

B. Relocation, temporary or permanent, and restoration of these facilities shall be in accordance with the practices and requirements of DTS and the Manual on Uniform Traffic Control Devices (MUTCD). Materials used in the installation and/or modification of traffic signal systems shall conform to the latest material specifications of DTS.

8.2.12 Oil Pipe Lines

A. Oil transmission lines and steam lines shall be relocated to clear the transit system. Work shall be performed by the pipeline owner or its designated contractor.

B. After consultation with RTD or their authorized representative, the Designer shall inform the pipeline company where the transit system will affect the company's facilities and shall coordinate the pipeline relocation design with the pipeline company.

END OF CHAPTER

Honolulu High-Capacity Transit Corridor Project

(Project)

DESIGN CRITERIA

CHAPTER 9

STRUCTURAL

May 22, 2009

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9.0 STRUCTURAL

9.1 GENERAL

9.1.1 Introduction

The basic design criteria for the structures on the Project are established in this chapter. Items in this category include aerial guideway structures, passenger stations, maintenance and ancillary facility structures.

9.1.2 Reference Data

A. The basic code for this project is the City and County of Honolulu (City) Building Code and shall govern structural designs for buildings and other structures not governed by American Association of State Highway and Transportation Officials (AASHTO) guidelines and specifications. This code adopts the 2006 International Building Code and International Residential Code with local amendments, September 18, 2007. This code and its amendments are referred to herein as the Building Code.

B. The basis of the design for aerial guideways shall be the AASHTO LRFD (Load and Resistance Factor Design) Bridge Design Specifications, 4th Edition, 2007, including all subsequent interim revisions as amended by the State of Hawaii Department of Transportation (HDOT) Highway Division Design Branch Design Criteria for Bridges and Structures dated April 15, 2008. The HDOT Design Criteria and their amendments are referred to herein as HDOT Code. The AASHTO LRFD Specification and applicable interim revisions and the AASHTO LRFD Construction Specifications are referred to herein as AASHTO LRFD. Seismic Design for new aerial guideways shall be in accordance with the HDOT Code and AASHTO Guide Specifications for LRFD Seismic Bridge Design (May 2007), herein referred to as AASHTO Seismic Guide Specs.

C. Structural-geotechnical design shall meet all applicable portions of the State of Hawaii general laws and regulations and the current editions of the codes, manuals, or specifications identified in this chapter of the Compendium of Design Criteria. Where the requirements stipulated in any of the above documents or by these criteria are in conflict, use the stricter, unless otherwise explicitly noted herein. Unless specifically noted otherwise in these criteria, the latest edition of the code, regulation, and standard that is applicable at the time the design is initiated shall be used. If a new edition or amendment to a code, regulation, or standard is issued before the design is completed, the design shall conform to the new requirement(s) to the extent practical or required by the governmental agency enforcing the code, regulation, or standard changed; and as agreed to by the City and County of Honolulu, Department of Transportation Services, Rapid Transit Division (RTD).

Where there are cases of special designs encountered that are not specifically covered by these criteria, the Designer shall bring them to the attention of RTD along with proposed criteria from standards of a recognized authority that address these special designs.

D. *Project Structural Engineer* is defined herein by procurement method.

1. *Design-build (D-B):* Design-builder's engineer of record's lead structural engineer who shall be a licensed professional structural engineer as defined by the State of

Hawaii Department of Commerce and Consumer Affairs (DCCA) and who shall be in responsible charge of all structural work and who shall affix his stamp and seal on all project design work. All work shall be subject to RTD review and acceptance.

2. *Design-bid-build (D-B-B):* Lead structural engineer who shall be a licensed professional structural engineer as defined by DCCA and who shall affix his stamp and seal on all project design work prepared for RTD either directly or indirectly as an employee of the engineer of record or as a sub-consultant to the engineer of record. All design work shall be subject to RTD review and approval.

E. All structural calculations provided in support of these criteria shall be sealed by a project structural engineer.

9.2 AERIAL GUIDEWAY STRUCTURES

9.2.1 General

Bridges and aerial structures that support rail transit loadings shall be designed using the requirements of the following applicable loadings, except as otherwise noted herein. When AASHTO LRFD is not applicable, the Manual for Railway Engineering of the American Railway Engineering and Maintenance of Way Association shall be used. Bridges and aerial structures that support rail transit loadings shall be designed for the maximum dead and live loads to which they may be subjected, including erection loads occurring during construction and the following other loads and forces:

A. Dead loads of structural components and nonstructural attachments (DC)

B. Superimposed dead loads (DW)

C. Live loads (LL)

1. Weight of Light Metro Vehicle with 3rd rail power supply (LMV)

2. Weight of maintenance car (HP)

D. Pedestrian live load (PL)

E. Derailment loads (DR)

F. Earthquake loads (EQ)

G. Friction force (FR)

H. Dynamic load allowance (IMV, IMH)

I. Centrifugal force (CE)

J. Longitudinal force (LF)

K. Earth pressure (EH)

L. Vertical pressure from dead load of earth fill (EV)

M. Live load surcharge (LS)

N. Downdrag force (DD)

O. Earth Surcharge Force (ES)

P. Water load, steam pressure, buoyancy, scour (WA)

Q. Wind load on structure (WS)

R. Wind load on live load (WL)

S. Force effects due to shrinkage (SH)

T. Force effects due to creep (CR)

U. Locked-in construction forces (EL)

V. Secondary forces from post-tensioning (PS)

W. Force effects due to uniform temperature (TU, TTR, TLR)

X. Rail fracture (RF)

Y. Force effects due to temperature gradient (TG)

Z. Force effects due to settlement (SE)

AA. Vehicular collision loads (CT)

BB. Vessel collision load (CV)

Loading criteria to which the structures are designed shall be shown on the Designer's structural drawings. Concrete placing and construction sequence shall be shown on the Designer's plans when required by design conditions. Provisions of agreements with property owners and other agencies regarding special loading for portions of structures that pass beneath or adjacent to their properties or facilities shall be considered in establishing the loading conditions for such structures. Attention shall be paid to proposed future construction.

All aerial structures and bridges shall be designed for sound walls. Dead load of 270 pounds per linear foot of structure shall be assumed per wall. Walls shall be considered to occupy either side of the structure or both sides simultaneously.

Temporary and Staged Construction:

A. The design of all segmental girder aerial structures: The construction forces resulting from the use of an erection gantry and locked-in forces. See Figure 9-1.

B. Construction Loads shall be considered in the design in accordance with AASHTO LRFD Section 5.14.2.

Figure 9-1. General Arrangement—Launching Gantry

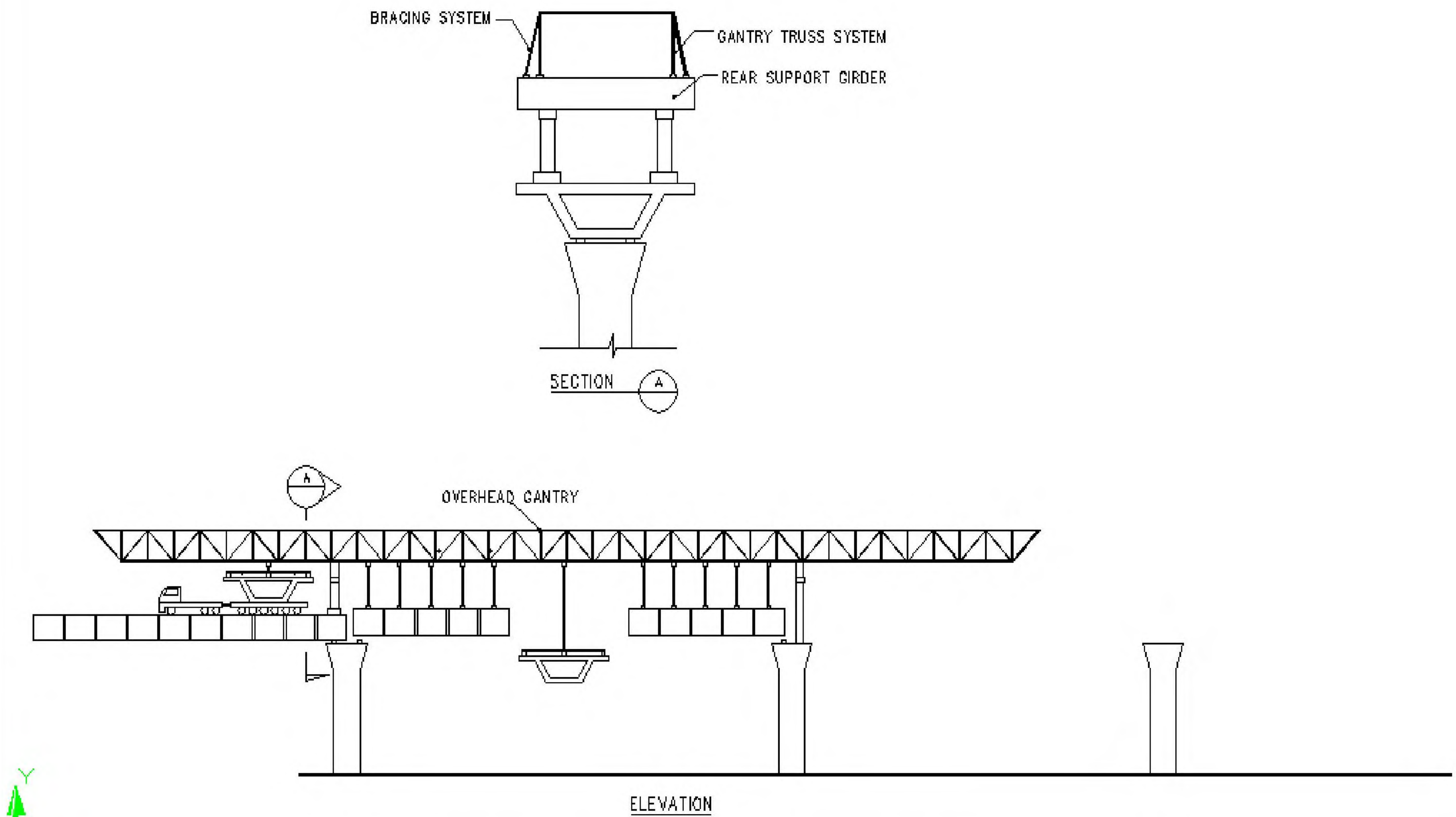


FIGURE 9-1
GENERAL ARRANGEMENT – LAUNCHING GANTRY
NOT TO SCALE

C. Seismic forces: Design response spectra shall be in accordance with HDOT Code. Seismic shall be considered in the following construction load combinations:

1. For Maximum Force effects:

   a. Q=1.0(DL+DIFF)+1.0CE+A+EQ

2. For Minimum Force effects:

   a. Q=1.0DC+1.0CE+A+EQ

9.2.2 Dead Loads (DC, DW)

Dead loads consist of the actual weight of the structure, permanently installed trackwork, partitions, service walks, pipes, conduits, cables, utilities, services, and all other permanent construction and fixtures. Component dead load (DC) shall consist of the weight of all components of the structure. Superimposed dead load (DW) shall include the weights of all appurtenances and utilities attached to the structure, including, but not necessarily limited to, the weights of the running rails, rail fasteners, concrete rail support (plinth) pads, emergency guardrails, contact rail and coverboard with mountings and support pads, walkways, wireways, cable trays, cables, railings and acoustical barriers. Dead loads for all elements shall account for deck camber, curvature and superelevation. Since dead load stresses are always present, the structure must be designed to sustain them at all times without reductions. For design of aerial guideways, unit weights and loads specified in Subsection 2.03 of HDOT Code shall be used. The dead load for all other structures shall be computed from the weights of the materials composing the structure and its permanent fixtures. The approximate unit weights of materials normally used in construction are shown in Table 9-1. A specific check should be made as to the actual weight where a variation might affect the adequacy of the design or where the construction may vary from the normal practice.

9.2.3 Live Loads (LL, PL)

Light metro vehicle with 3rd rail power supply (LMV): The FTA Transit Cooperative Report Program 57 designates vehicle design live loading as AW0, AW1, AW2, AW3, and AW4:

A. AW0 is the total revenue service ready dead weight

B. AW1 is AW0 plus all seated passengers at 155 pounds each

C. AW2 (design load) is AW1 plus standing passengers at 4 standees per square meter

D. AW3 (crush load) is AW1 plus standing passengers at 6 standees per square meter

E. AW4 (vehicle structure design) is AW1 plus standing passengers at 8 standees per square meter

Light metro vehicle with 3rd rail power supply (LMV) using AW3 shall be used for live loads. The data presented in Figure 9-2 should be used for initial design, recognizing that structural calculations will be required to confirm the adequacy of the final design after the vehicle characteristics are confirmed. In all cases, the combination of train lengths used for structural design shall be the one that produces the most severe conditions on the element being designed. The number of vehicles considered in an LMV train shall vary from one to the number required to add up to approximately 240 feet in total train length.

Table 9-1. Weights of Materials

Material	Weight
Aluminum alloy	175 pcf
Asphalt mastic, bituminous macadam	150 pcf
Ballast, crushed stone, compacted earth	120 pcf
Ceilings, plaster board, unplastered	3 psf
Gypsum ceiling tile, 2" unplastered	9 psf
Pressed steel	2 psf
Ceramic glazed structural facing tile, 4"	33 psf
Concrete: plain or reinforced; gravel aggregates	160 pcf
Special and lightweight concretes	110 pcf*
Floors: gypsum floor slab, per inch of depth	5 psf
Asphalt mastic	5 psf
Ceramic tile, on 1" mortar bed	23 psf
Terrazzo, 1" on 1/2" mortar bed	18 psf
Marble, 1" on 1/2" mortar bed	20 psf
Linoleum	2 psf
Maple, 7/8" on sheathing, 2" cinder fill, no ceiling	18 psf
Oak, 7/8" on sheathing, wood joists at 16" centers, no ceiling	11 psf
Glass	160 pcf
Gravel, sand	120 pcf*
Iron, cast	450 pcf
Partitions: plaster, 2" channel stud, metal lath	20 psf
Plaster, 4" channel stud, metal lath	32 psf
Hollow plaster, 4” metal lath	22 psf
Gypsum block solid, 3"—both sides plastered	19 psf
Gypsum block, hollow, 5"	22 psf
Marble wainscoting, 1"	15 psf
Steel partitions	4 psf
Ceramic glazed structural tile, 4"	33 psf
Rails and fastenings, per track (2 rails)	130 plf
Third rail	32 plf
Roofs: roofing felt, 3 ply, and gravel	5-1/2 psf
5 ply	6-1/2 psf
Sheathing, 3/4" thick	3-1/2 psf
Steel	490 pcf
Timber: untreated	48 pcf
Timber: treated	60 pcf
Walls: brick solid, per inch	10 psf
Walls: terra cotta tile 4"—plastering, add 5 psf per side	25 psf
Glass, structural, per inch	15 psf
Windows, frame, glass, sash	8 psf
Stone, 4"	55 psf
Steel sheeting, 14 gauge	3 psf

*See HDOT Code for special weight conditions
pcf = pounds per cubic foot
psf = pounds per square foot
plf = pounds per linear foot

Figure 9-2. LMV Loading Diagram

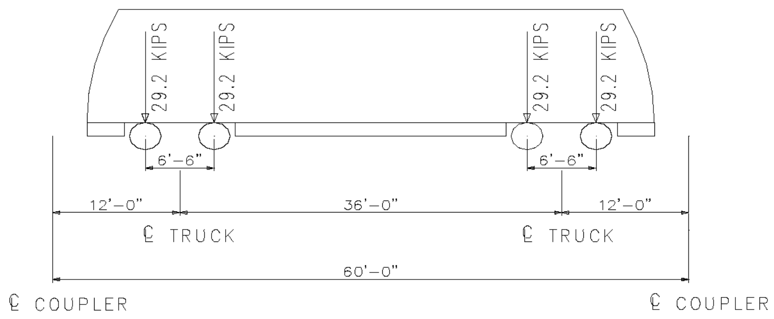
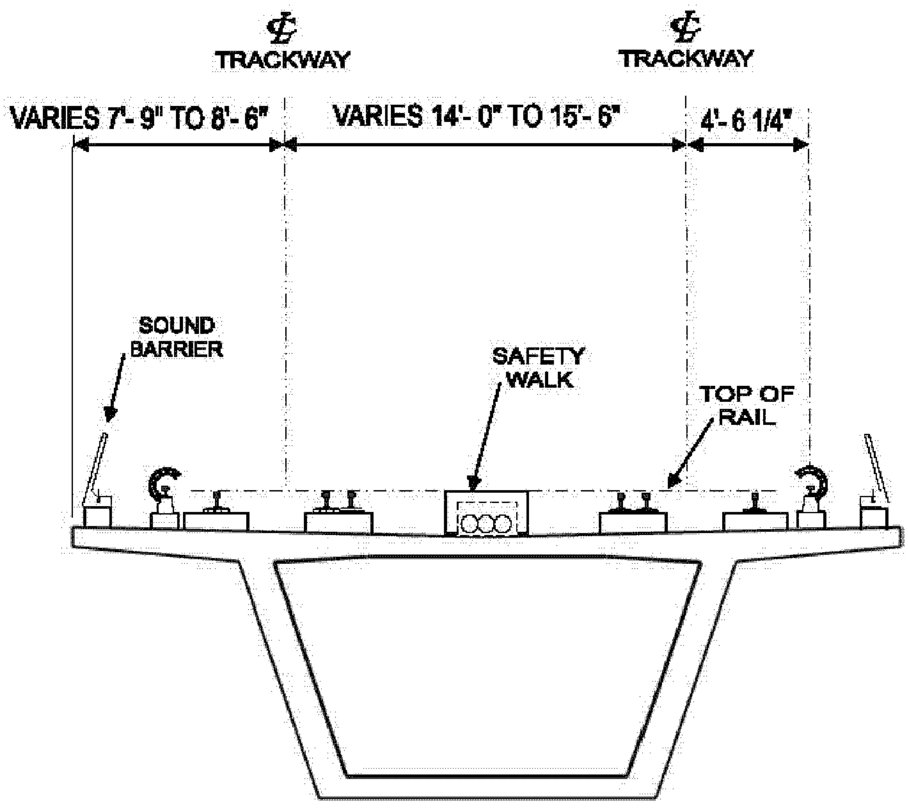


Figure 9-3. LMV Girder Configuration



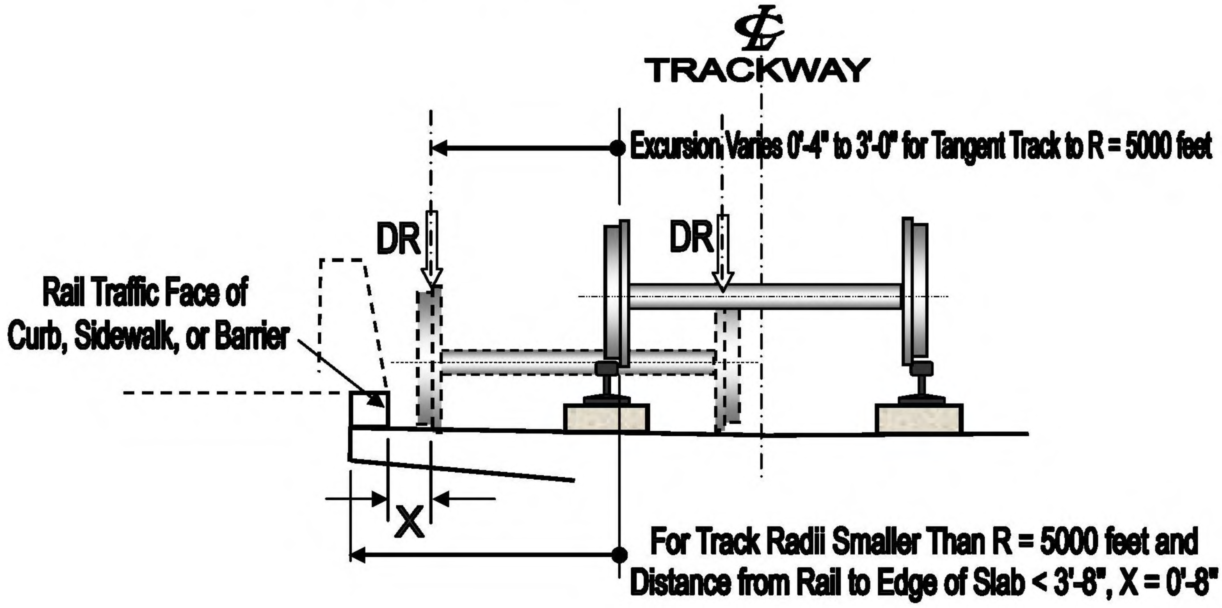
9.2.4 Derailment Loads (DR)

Guideway structures supporting LMV trains are subject to derailment forces. These shall be applied as follows.

9.2.4.1 Vertical

The vertical derailment load shall be taken as that produced by fully loaded vehicles placed with their longitudinal axes parallel to the track. Lateral vehicle excursion shall vary from 4 inch minimum to 3 feet 0 inches maximum for tangent track and curved track with radii greater than 5,000 feet. For track with smaller radii and where the distance from the rail to the edge of the deck slab is less than 3 feet 8 inches, the maximum excursion shall be adjusted so that the derailed wheel flange is located 8 inches from the rail traffic face of the nearest barrier, if any, or the edge of the deck. See Figure 9-4.

Figure 9-4. Lateral Vehicle Excursion for Vertical DR Load



A vertical impact factor of 100 percent of vehicle weight shall be used to compute the equivalent static derailment load. This vertical impact shall be in lieu of the dynamic load allowance provided in Section 9.2.6.

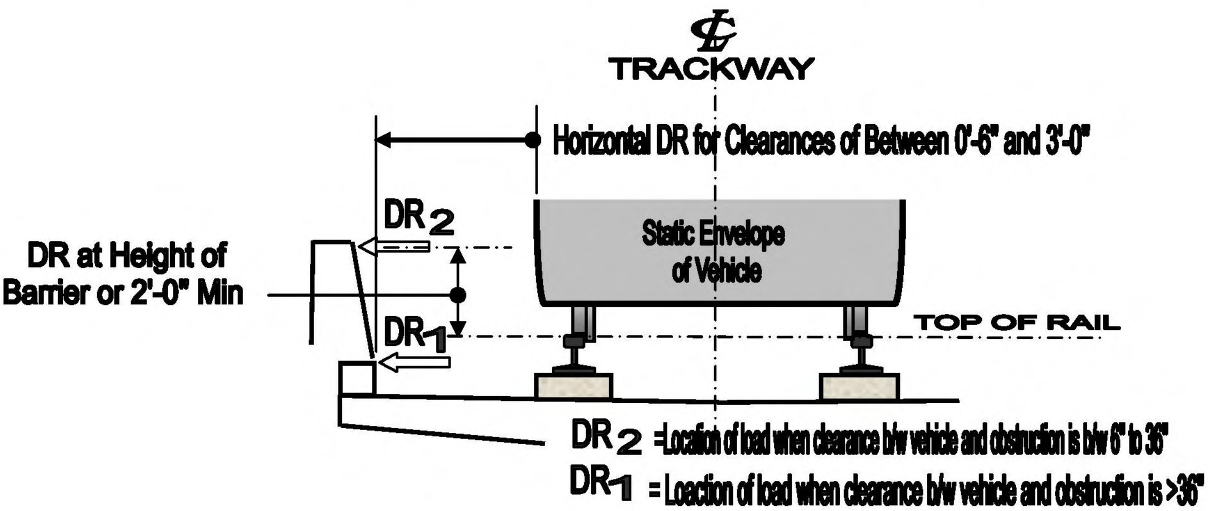
When checking any component of superstructure or substructure that supports two or more tracks, only one train on one track shall be considered to have derailed, with the other track being loaded with a stationary train without impact. All elements of the structure shall be checked assuming simultaneous application of all derailed wheel loads. However, the reduction of positive moment in continuous slabs due to derailed wheel loads in adjacent spans shall not be allowed.

9.2.4.2 Horizontal

Aerial guideways and guideways supported on embankments more than 4 feet above the surrounding grade shall be provided with restraining rails on the inside running rail on all curves on a radius of less than 500 feet. In addition, a concrete curb a minimum of 8 inches high shall be provided at the outside edge of the guideway or embankment that is above and composite with the structure supporting the guideway and structurally capable of sustaining the DR prescribed in the paragraph below.

For guideway cross-sections having a clearance between the vehicles and the barrier walls of between 6 inches and 3 feet 0 inches, with LMV speed of 55 mph or greater, the force due to horizontal DR shall be taken as 40 percent of a single fully loaded vehicle acting 2 feet above the top of rail and normal to the barrier wall for a distance of 10 feet along the wall (See Figure 9-5). For guideway cross-sections having a clearance between vehicles and adjacent obstructions of greater than 3 feet 0 inches, the centerline of the trackway shall be located so that the face of an 8-inch curb can be provided with a minimum of 3 feet 0 inches from the face of the obstruction and capable of sustaining the DR prescribed in the above paragraph (See Figure 9-5).

Figure 9-5. Lateral Force Distribution for Horizontal DR Load



9.2.5 Earthquake Loads (EQ)

A. All aerial structures and bridges shall be designed to resist earthquake motions in accordance with the HDOT Code and AASHTO Seismic Guide Specs. In some cases, aerial structures with bridges may be under jurisdictions other than RTD and design criteria specified elsewhere.

B. Earth retaining structures shall be designed to resist lateral earth pressure induced by earthquakes as recommended by the Geotechnical Engineering Report provided for the Project.

C. All other structures shall be designed to resist earthquake motions in accordance with applicable building codes.

9.2.6 Dynamic Load Allowance (IMV, IMH)

Dynamic load allowance is the statically equivalent dynamic effect resulting from vertical and horizontal acceleration of the LL given as a percent of LL.

A. Dynamic load allowance considerations for aerial structures supporting rail transit loading shall be as follows:

1. Dynamic load allowance shall be used for the design of the superstructure and generally to those members of the structure that extend down to the main footings as well as the portion above the ground line of concrete or steel piles rigidly connected to the superstructure. Dynamic load allowance shall not be used for abutments, retaining walls, wall-type piers, embedded piles, footings, and service walks. Dynamic load allowance shall not be applied to the maintenance car (HP).

2. Vertical dynamic load allowance (IMV) for aerial structures shall be 33 percent of LL.

3. In addition to IMV provided above, a horizontal dynamic load allowance (IMH) equal to 10 percent of LL shall be applied. This force shall be equally distributed to the individual axles of the vehicle and shall be assumed to act in either direction transverse to the track through a point at 3.5 feet above the top of the low rail. The horizontal force component transmitted to the rails and supporting structure by an axle shall be concentrated at the rail having direct wheel flange to rail head contact. When IMH acts simultaneously with CE, only the larger of the two forces needs to be considered.

B. Design of the top slab of utility vaults and other underground structures supporting highway loading shall conform to the following:

$$IM = 33(1.0 - 0.125D_e) > 0\%$$

where: D_e = Minimum depth of earth cover above the structure (feet)

The depth of cover shall be measured from the highest top of ground or paving to the top of the underground structure.

C. Structures supporting special vehicles, such as moving equipment or other dynamic loadings that cause significant impact, shall conform to the local building code or, if not covered by code, shall be considered individually using the best technical information available.

9.2.7 Centrifugal Force (CE)

Structures on curves shall be designed for a horizontal radial force (CE) equal to the following percentage of the LL, without Dynamic Load Allowance, in all trackways:

$$CE = f\,(V)^2 / gR$$

where: g = 32.2 feet/second^2
V = design speed (feet/second)
f = 4/3 for load combination other than fatigue and 1.0 for fatigue
R = the radius of the curve of the track centerline (feet)-

The centrifugal force shall be applied 4 feet above the top of low rail on all tracks.

9.2.8 Longitudinal Force (LF)

9.2.8.1 Forces due to Acceleration and Deceleration

Provision shall be made for LF due to the train acceleration and deceleration. The magnitude of LF shall be computed as follows:

A. For decelerating trains, LF shall be equal to 28 percent of LL without dynamic load allowance.

B. For accelerating trains, LF shall be equal to 14 percent of LL without dynamic load allowance.

This force shall be applied to the rails and supporting structure as a uniformly distributed load over the length of the train in a horizontal plane at the top of the low rail. Consideration shall be given to various combinations of acceleration and deceleration forces where more than one track is carried by the structure.

9.2.8.2 Forces due to Restraint of Continuous Welded Rail

Wherever a continuous welded rail (CWR) is terminated, provision shall be made to fully restrain its end. This restraint shall be assumed to introduce an LF in the end of each rail of 165,000 pounds based on 85ºF temperature change. Unless aerial structures and direct fixation bridges are designed to resist this force, CWR shall not be terminated thereon. See Trackwork Standard Drawings.

Termination, as used in the above paragraph, means *absolute termination*. The placement of a turnout or crossover between ends of CWR does not necessarily result in absolute termination of the rail; the CWR is not considered to be terminated if some means is provided, through the turnout or crossover, to transmit the above force from the end of one rail to the end of the other. The rail shall extend beyond the aerial or bridge structure such that a minimum of 100 rail fasteners, adjacent to each other, are engaged in the continuous at-grade or underground portions of the track.

9.2.8.3 Forces due to Rail Bumping Posts

A rail-mounted vehicle retarding device in the form of bumper posts shall be used on stub-end tracks located in yards, on main lines, or on sidings.

The transfer of loads due to collision between any number of rail transit cars, traveling at the design speed and any structure-mounted rail bumping post shall be limited to 200 kilo pounds (kips), including impact. The bumping post shall be attached only to the rail it protects and shall transfer load to the structure only through rail seat assemblies. The structure will be designed for the loads transmitted through the rail seat assemblies for only one bumping post being activated at one time.

To further protect the structure, the bumping post shall be designed with mountings so that excess loads will cause the bumper to slide over a safe distance. As an alternative to a frangible mounting, the design shall preclude any device that would cause the transferred loads to exceed 200 kips. For structural design, the bumping post load shall be evenly divided between the two rails it is attached to. Structures shall be designed to resist the lesser of 200 kips or the total available restraint provided by the rail seat assemblies on the structure supporting the rails and the bumping post in question.

9.2.9 Earth Pressures (EH, EV, LS)

A. Earth pressures shall be as specified in AASHTO LRFD Section 3.11

B. Surcharge loads values shall not be less than those specified in AASHTO LRFD Section 3.11.6.

1. Rail transit loading shall be based on actual axial loads, including impact factor, and car spacing.

2. Vehicle [non-rail transit] loading shall be in accordance with AASHTO LRFD Section 3.11.6.

3. LL and DL from adjacent foundations of structures within the zone of influence shall be considered in computing horizontal pressures on new or existing structures. The zone of influence is defined as being a line projected downward at a slope of 1H:1V from the outside edges around the entire perimeter.

4. The lateral earth pressures to be used in design of structures either fully or partially embedded in “rock” shall be per the recommendations of the project geotechnical engineer as defined in the geotechnical section herein.

9.2.10 Water Load, Stream Pressure, Buoyancy, Scour (WA)

Design ground water shall be in accordance with recommendation from the project geotechnical engineer and geotechnical data obtained from subsurface data. In addition, design surface water levels, if any, shall be in accordance with site/area-specific hydraulics report. The effects of hydrostatic pressure and buoyancy shall be considered whenever groundwater is present or may be present at a future date. The possibility of future major changes in groundwater elevation shall be considered. The total weight of structure and backfill shall always exceed the calculated uplift due to buoyancy by 10 percent. The design shall take into account the effect of hydrostatic pressures pertaining to construction sequence. The backfill shall be considered as the volume contained within vertical planes defined by the outside limits of the structure. Soil resistance on the sides of the structure and vertical planes defining outside limits of the structure shall not be included in resistance to buoyancy calculation.

Local flooding may add to loading on structures within the flood plain. Anticipated flood elevations shall be determined by a study of official flood records. The consequences of changes in foundation conditions resulting from the “check flood” for bridge scour and “design flood” for scour shall be considered. Water load shall be included in the design of aerial structures where applicable. All piers and other portions of structures that are subject to flood forces shall be designed in accordance with the requirements outlined in AASHTO LRFD and HDOT Code.

Guideways that cross over flood control channels and rivers shall meet requirements of the City and County Flood Control Districts and the Corps of Engineers.

9.2.11 Wind Load on Structure (WS)

The aerial structures shall be designed to withstand wind loads of uniform pressure acting upon the superstructure, substructure, and live load (see the wind load on live load section below).

9.2.11.1 Wind Load on Superstructure

A horizontal uniform wind load of the intensities given by AASHTO LRFD shall be applied simultaneously at the centroid of all exposed areas.

9.2.11.2 Wind Load on Substructure

The substructure shall be designed to withstand the preceding loads applied to the superstructure as they are transmitted to the substructure. In addition, a horizontal wind load of magnitude specified in AASHTO LRFD in any direction shall be applied simultaneously at the centroid of the exposed projected substructure area.

9.2.12 Wind Load on Live Load (WL)

A. For trains operating on aerial structures with the underside of the main girders not more than 40 feet above the mean retarding surface, WL shall consist of a transverse wind load of 115 plf of train and a longitudinal wind load of 28 plf of train. These loads shall be applied simultaneously. The transverse force shall be applied to the rail and superstructure as loads concentrated at the axle locations and in plane 6 feet 4 inches above the top of the lower rail. The longitudinal force shall be applied to the rails and superstructure as a load uniformly distributed over the length of the train in a horizontal plane 6 feet 4 inches above the top of the lower rail.

B. For higher aerial structures, the values of WL in the transverse and longitudinal directions shall be as follows:

H = 41 feet to 60 feet

where: Transverse wind pressure = 126 plf
Longitudinal wind pressure = 31 plf

H = 61 feet to 100 feet

where: Transverse wind pressure = 130 plf
Longitudinal wind pressure = 34 plf

Where H is measured from the mean retarding surface to the underside of the main girder.

These loads apply to the design of substructure elements supporting a single track. For the design of substructure elements supporting two tracks, these loads shall be increased by 30 percent when both tracks are loaded; this factor accounts fully for shielding effect of vehicle-on-vehicle as the two trains run alongside each other.

9.2.13 Force Effects due to Temperature Gradient (TG)

Temperature gradient shall be considered, if applicable. Internal stresses and structural deformations due to both positive and negative temperature gradients may be determined in accordance with the provision of AASHTO LRFD Section 3.12.3.

9.2.14 Force Effects due to Shrinkage and Creep (SH, CR)

Stresses and movements resulting from concrete shrinkage and creep shall be incorporated into the design of the structures in accordance with AASHTO LRFD. Refer to NFPA 130, CEB-FIP 1990, for creep and shrinkage coefficients.

9.2.15 Force Effects due to Uniform Temperature (TU, TTR, TLR)

A. Provision shall be made for stresses and deformations resulting from temperature ranges as follows.

1. Concrete
   a. Temperature range = $T_{maxDesign}$ - $T_{minDesign}$ = 60ºF (see HDOT Code)
   b. Coefficient of expansion .0000060 inch/inch/ºF
2. Steel
   a. Temperature range = $T_{maxDesign}$ - $T_{minDesign}$ = 75ºF (See AASHTO LRFD)
   b. Coefficient of expansion .0000065 inch/inch/ºF
3. Direct Fixation Track
   a. Controlled setting temperature
   b. 80ºF minimum
   c. 95ºF maximum
   d. Temperature rise 34ºF maximum
   e. Temperature fall 43ºF maximum
   f. Coefficient of expansion 0.0000065 inch/inch/ºF

The temperature ranges specified above are based on a range of ambient air temperature of 52ºF (minimum) to 94ºF (maximum). The CWR is assumed to achieve a minimum temperature of the ambient air temperature and a maximum temperature of 20ºF above the ambient air temperature.

B. For direct fixation track, provision shall be made for transverse and longitudinal forces due to temperature variations in the rail. These forces shall be applied in a horizontal plane at the top of the low rail as follows:

1. Transverse Force (TTR): The transverse force per linear foot of structure per rail shall be determined by the following formula:

   T = 151 Kips/R

   where: R = radius of curvature in feet

2. Longitudinal Force (TLR): The longitudinal force per structure per rail shall be determined by the smallest of 200 kips or by the following formula:

   T = 0.65 x P x L

   where: P = longitudinal restraint force of rail per linear foot
   L = average length of adjacent structures (feet)

9.2.16 Rail Fracture (RF)

The final design of structures shall consider the possibility of any one CWR breaking under a tensile load of 200 kips. The break will be restrained by a longitudinal restraint force in the range of 1,600 pounds to 2,200 pounds per rail seat assembly. The structures will be designed for the possibility of only one rail break at one time.

Structures shall be designed to resist the lesser of 200 kips from the rail break or the total available restraint available from the rail seat assemblies on the structure for that rail. Rail seat assemblies will be spaced typically at 30 inches on-center except at bonded rail joints and at special trackwork.

At special trackwork locations, design details for anchoring rails using the same type of rail fasteners as the typical structures shall be provided.

9.2.17 Force Effects due to Settlement (SE)

Load(s) induced on the structures by differential settlement shall be considered in the loading combination. Consider this load similar to shrinkage and thermal forces or in the section on settlement and deflection below. Requirements for allowable differential settlements are prescribed in the geotechnical section below.

9.2.18 Vehicular Collision Loads (CT)

Piers or other support elements for elevated guideways or roadways which have less than 30 feet clearance from the edge of travel way of an adjacent roadway, or less than 50 feet from the centerline of a railway track, shall be designed to withstand a horizontal static force of 400 kips, unless protected with suitable barriers. This force is assumed to act in any direction in a horizontal plane at a height of 4 feet above ground level. This condition occurs with the dead load of the structure but need not be applied concurrently with other applied loadings.

9.2.19 Design Specifications

Use the AASHTO LRFD method for the design of all structural components and connections. Each component and connection shall satisfy each of the following limit states, unless noted otherwise:

9.2.19.1 Service limit state

A. Service I: Load Combination relating to operational use of the guideway with operational wind.

B. Service II: Load Combination intended to control yielding of steel structures and slip of slip-critical connections due to live load.

C. Service III: Load Combination for longitudinal analysis relating to tension in prestressed concrete structures with the objective of crack control and to principal tension in the webs of segmental concrete girders.

D. Service IV: Load Combination relating only to tension in prestressed concrete substructures with the objective of crack control.

E. Service V: Load Combination relating to non-operational use of the guideway with high velocity wind.

F. Service VI: Load Combination relating to only to control uplift and concrete tension during derailment.

G. Service VII: Load Combination relating only to segmental bridges, with no live loads and full temperature gradient.

9.2.19.2 Fatigue and fracture limit state

A. Fatigue I: Fatigue and fracture load combination relating to repetitive live load and dynamic response.

9.2.19.3 Strength limit state

A. Strength I: Load Combination relating to operational use of the guideway without wind.

B. Strength II: Load Combination relating to use of Owner-specified permit vehicles without wind.

C. Strength III: Load Combination relating to non-operational use of the guideway with high velocity wind.

D. Strength IV: Load Combination relating very high dead load to live load force effect ratios.

E. Strength V: Load Combination relating to operational use of the guideway with operational wind.

F. Strength VI: Load Combination relating to operational use of the guideway with emergency braking.

9.2.19.4 Extreme event limit state

A. Extreme Event I: Load Combination relating to operational use of guideway during a seismic event for connection of superstructure to substructure only.

B. Extreme Event II: Load Combination relating to operational use of guideway during a vessel or truck collision. (Vessel and truck collision are considered to be separate events and should not be applied simultaneously).

C. Extreme Event III: Load Combination relating to operational use of the guideway during a derailment.

D. Extreme Event IV: Load Combination relating to a rail fracture.

E. Extreme Event V: Load Combination relating to superflood (500 year) scour event.

Limit states are defined herein to establish a set of performance criteria that shall be met for given loading conditions. These loading conditions combine various loads which can occur simultaneously during operational and non-operational service.

9.2.20 Application of Loadings

Where applicable, use loads and forces listed above for the design of rail transit aerial structures. Rail transit vehicle live loads, buoyancy, wind loads and other variable loads shall be reduced or eliminated to create the maximum force effect on the structure. When all or a portion of deck width is dedicated exclusively to rail transit, apply only the rail transit loads to that width.

9.2.21 Multiple Presence Factor

For structures carrying rail transit loads, tracks shall be treated as a traffic lane in applying the provisions of AASHTO LRFD, except the multiple presence factor for the first two loaded tracks shall be 1.0 and for three or more loaded tracks shall be 0.85.

9.2.22 Special Design Considerations

9.2.22.1 Vibration

A moving vehicle exerts a dynamic effect on the guideway resulting from a highly complex interaction of the vehicle suspension system, vehicle speed, and roughness of the riding surface with the guideway. In order to avoid resonance and provide passenger comfort, the dynamic interaction between the vehicles and the guideway structure shall be performed.

To limit vibration amplification due to the dynamic interaction between the superstructure and the rail car(s), the first-mode natural frequency of flexural vibration of each simple span guideway should generally be not less than 2.5 hertz and no more than one span in a series of three consecutive spans should have a first-mode natural frequency of less than 3.0 hertz.

Special analysis shall be performed for any bridge or for superstructures having a first mode of vertical vibration less than 2.5 hertz or for the condition when more than one span in a series of three consecutive spans has the first mode of vibration less than 3.0 hertz. To assure passenger comfort, the vehicle amplitude of the vehicle – structure dynamic response must be limited to 0.05 g, where g is the acceleration of gravity.

This special analysis shall model the proposed structure and the transit vehicle. The analysis shall contain a sufficient number of degrees of freedom to allow modeling of the structure, vehicle truck spacing, vehicle primary suspension, vehicle secondary suspension, and the car body. It shall make provision for the placement of the vehicle on the structure in various locations to model the passage of the transit vehicle. When the exact configuration of either the vehicle or the structure is not known, the analysis shall assume a reasonable range of parameters and shall model combinations of those parameters as deemed appropriate.

The analysis shall determine whether vertical dynamic load allowance loads in excess of 33 percent of LL are required for the design of the structure.

Thermal force interaction between the structural components and the trackwork system shall be considered, as specified in the section on force effects due to uniform temperature above.

9.2.22.2 Fatigue

The effect of stress level changes caused by passage of rail trains over structures shall be considered using 3 million cycles of maximum stress over the life of the structure to estimate the number of repetitive maximum stress cycles.

9.2.22.3 Uplift

There should be no uplift at any support for any combination of service loading. See the section on loading combinations herein.

9.2.22.4 Friction

Friction shall be considered in the design where applicable.

9.2.22.5 Sound Barriers

Sound barriers, both presence and absence, shall be considered in the evaluation of vibration and deflection limits.

9.2.22.6 Bearings

AASHTO LRFD shall be used for design of bearings.

9.2.22.7 Camber and Deflections for Aerial Guideway Structures

As a guide in design, the total long-term predicted camber growth, less deflection due to full dead load, shall be limited to 1/2000 of the span length for non-ballasted, prestressed concrete aerial structures, unless approved otherwise by RTD.

To ensure rider comfort, the deflection of longitudinal girders under normal live load plus dynamic load allowance shall not exceed 1/1000 of the span length. For main cantilever girders, the deflection under normal live load with dynamic load allowance shall not exceed 1/375 of the cantilever span.

The differential deflection of the slab immediately below the centerline of the two rails of the same track, due to girder and slab deformations, shall not exceed 1/5000 of the span length.

9.2.22.8 Longitudinal Tension Stresses in Prestressed Members

HDOT Code shall be used for allowable longitudinal tension stresses. Tension stresses are not allowed in pre-compressed tensile zones after all losses have occurred.

9.2.22.9 Structure Deformations and Settlements

The control of deformations through proper structural design is of paramount importance in obtaining acceptable ride quality for the transit vehicles and passengers. Consider all structure deformations, including foundation settlement, not only for the effects on structural behavior but also for their effect on trackwork. As a minimum, guideway piers and abutments settlement as measured at the top of concrete of the finished guideway girder deck shall be limited as prescribed in the section on settlement and deflection below.

9.2.22.10 Additional Requirements for Segmental Guideway Construction

A. Shear and torsion design to conform to AASHTO LRFD Section 5.8.6.

B. Principal tensile stresses in webs to conform to AASHTO LRFD Section 5.8.5.

C. If hollow precast columns are used, the columns shall have access opening for future inspection. The columns shall have a solid section minimum 5 feet above finished grade or 12 feet above high water level. Vertical Post-tensioning is not allowed in the solid sections.

D. Dry joints not allowed in the superstructure and substructure precast elements with match cast joints.

E. Box girders shall be transversely post-tensioned. No transverse pre-tensioning is allowed.

9.2.22.11 Crack Control

The design of prestressed concrete aerial structures shall consider the effect of temporary loads imposed by sequence of construction stages, forming, falsework, and construction equipment, as well as the stresses created by lifting or placing pre-cast members, stress concentration (non-uniform bearing at the ends of pre-cast beams), end block design and detailing, methods of erection, shrinkage, and curing. Ensure that the structural design of all pre-stressed or reinforced concrete members is adequate and clear and that specifications are prepared which are compatible with the design so that objectionable cracking does not occur in erection or service.

9.2.23 LOADING COMBINATIONS

The following groups (Table 9-2) represent various combinations of loads and forces to which a structure may be subjected. Each structural component shall be designed for the appropriate load combination limit states and load factors as specified in AASHTO LRFD. Additionally, for segmentally constructed bridges, consider load combination in AASHTO LRFD equation 3.4.1-2 for service limit state (Service VII in Table 9.2).

9.2.24 LOAD DISTRIBUTION

Distribute live loads in accordance with provisions of AASHTO LRFD, except as noted herein. Modify AASHTO LRFD by the following additions:

9.2.24.1 Ballasted Track

Axle loads may be assumed as uniformly distributed longitudinally over a length of 3 feet, plus the depth of ballast under the tie, plus twice the effective depth of slab, except as limited by axle spacing.

Table 9-2. Load Combination and Load Factors

	Permanent Loads		Transient Loads				Loads Due to Volumetric Change			Exceptional Loads				
Load Combination Limit State	DC DD DW EH EV ES EL PS CR SH	SE	LL IMV IMH CE LF PL LS	WA	WS	WL	FR	TU** TTR** TLR**	TG	EQ	CT	CV	DR	RF
Strength I	γ_p	1.00	1.70	1.00	-	-	1.00	0.5/1.20	-	-	-	-	-	-
Strength II	γ_p	1.00	1.40	1.00	-	-	1.00	0.5/1.20	-	-	-	-	-	-
Strength III	γ_p	1.00	-	1.00	1.40	-	1.00	0.5/1.20	-	-	-	-	-	-
Strength IV	γ_p	-	-	1.00	-	-	1.00	0.5/1.20	-	-	-	-	-	-
Strength V	γ_p	1.00	1.40	1.00	0.40	1.40	1.00	0.5/1.20	-	-	-	-	-	-
Strength VI	γ_p	1.00	1.40	1.00	-	-	1.00	0.5/1.20	-	-	-		-	
Extreme Event I	γ_p	-	1.0*	1.00	-	-	1.00	-	-	1.10	-	-	-	-
Extreme Event II	γ_p	-	1.0*	1.00	-	-	1.00	-	-	-	1.10	1.10	-	-
Extreme Event III	γ_p	-	1.0*	1.00	-	-	1.00	-	-	-	-	-	1.30	-
Extreme Event IV	γ_p	1.00	-	-	-	-	1.00	0.5/1.20	-	-	-	-	-	1.30
Extreme Event V	γ_p	-	1.0*	1.00	-	-	1.00	-	-	-	-	-	-	-
Service I	1.00	1.00	1.00	1.00	0.30	1.00	1.00	1.00/1.20	γ_{TG}	-	-	-	-	-
Service II	1.00	-	1.30	1.00	-	-	1.00	1.00/1.20	-	-	-	-	-	-
Service III	1.00	1.00	0.80	1.00	-	-	1.00	1.00/1.20	γ_{TG}	-	-	-	-	-
Service IV	1.00	1.00	-	1.00	0.70	-	1.00	1.00/1.20	-	-	-	-	-	-
Service V	1.00	1.00	-	1.00	1.00	-	1.00	1.00/1.20	γ_{TG}	-	-	-	-	-
Service VI	1.00	1.00	1.00	1.00	-	-	1.00	1.00/1.20	γ_{TG}	-	-	-	1.00	-
Service VII	1.00	-	-	1.00	-	-	-	-	γ_{TG}	-	-	-	-	-
Fatigue	-	-	1.00	-	-	-	-	-	-	-	-	-	-	-

* Live load from Light Metro Vehicle (LMV)—loaded only on one track.
** Larger value shall be used for deformations and the smaller value for all other effects.
*** Fatigue Load Combination shall include LL, IMV, IMH & CE only.
γ_p Values, See AASHTO LRFD Table 3.4.1-2, Load Factors for Permanent Loads, except as noted herein.
γ_p Values for PS, CR and SH; see AASHTO LRFD Table 3.4.1-3, Load Factors for Permanent Loads Due to Superimposed Deformations.
γ_p Value for EL shall equal the value for DC.
γ_{TG} Value for Service I, III, V & VI shall be 0.5, value for Service VII shall be 1.0.

Wheel loads may be assumed to have uniform lateral distribution over a width equal to the length of the tie plus the depth of ballast under the tie, except as limited by the proximity of adjacent tracks or the extent of the structure.

9.2.24.2 Direct Fixation Track

Where wheel loads are transmitted to the deck slab through rail mountings placed directly on the slab, the wheel load shall be assumed as uniformly distributed over a length of 3 feet along the rail. This load may be distributed transversely (normal to the rail and centered on the rail) by the width of the rail fastener pad plus twice the depth of the deck and track concrete.

For derailment loads where the vehicle wheels bear directly on the slab, the wheel loads shall be assumed to be distributed over 3 feet of the slab in a direction perpendicular to the main reinforcement.

9.3 SURFACE STATIONS AND BUILDINGS

Surface stations are defined as those stations with platforms constructed at or below adjacent finished grade (at-grade stations). Design the following structures and buildings (but not limited to the following) included in the Project in accordance with the Building Code when the structures do not participate in the loads carried by the aerial guideway girders.

A. All building framing and components for surface stations, excluding aerial station platforms, mezzanines, and aerial pedestrian access/ramps

B. Maintenance facilities

C. Ancillary facilities

    1. New building(s) by private developers representing commercial interests or other public agencies that are planning pedestrian entrance access to RTD facilities must have their designs reviewed and accepted by RTD. It is the general policy of RTD to review designs on a case-by-case basis. This includes not only plans for physical attachment but also all new construction within the influence zone of the existing RTD facilities.

    2. Foundation and soils investigations and reporting requirements shall be in accordance with Section 1802 of the Building Code, except as modified herein.

    3. Temporary support of project facilities during the adjacent excavation for new buildings will be such that at any level, the project facilities lateral displacement shall not exceed 0.001 times its overall height above the bottom of the base slab, but not to exceed 1/2 inches without Engineer’s prior approval. Unless otherwise approved by RTD in advanced and in writing, the lateral forces used for the design of temporary excavation support shall consider both the static and dynamic loads for which the project facility was designed. Temporary support shall not endanger the safety of any persons or cause damage to any property and shall conform to HDOT Standard Specifications Section 107.12.

    4. Areas of new buildings adjacent to project facilities where the public has access or that cannot be guaranteed as a secure area, such as parking garages and commercial storage and warehousing, shall be treated as areas of potential explosion. NFPA 130, Standard for Fixed Guideway Transit Systems, life safety separation criteria shall be applied that assumes such spaces contain Class-I flammable or Class-II or Class-III combustible liquids. For structural and other

considerations, separation and isolation for blast shall be treated the same as for seismic, and the more restrictive shall be applied.

5. Parapets

Where parapets are used, they shall be designed to withstand dead load, wind load, force due to thermal expansion and contraction, shrinkage force, and earthquake forces equal to the full dead load of the parapet acting at the center of mass of the component parts.

6. Elevators

Surface structures shall be designed for the loads described below:

a. Dead load of structure

b. Live load of 100 plf applied at the free edges of the frame

c. Wind load of 40 psf on windward side

d. For traction type elevators, the surface structure shall be designed to support elevator beams. The end reaction of the elevator beams shall be 18,000 pounds minimum. The location of the elevator beams varies with the type of elevator and its relative machine room location. The Designer shall coordinate with elevator manufacturers regarding elevator beam locations.

D. Escalators

The support elements shall be designed for the end reactions from the escalators. The end reactions shall be provided to the Designer by RTD.

E. Elevators, Escalators, and Passenger Conveyors

Structures supporting elevators, escalators, or passenger conveyors shall be designed for the maximum reactions from any of the manufactured units considered for use in the system.

F. Stairs

Stairways shall be designed for a uniform LL of 100 psf or a concentrated load of 300 pounds on the center of stair treads, whichever is critical. Impact shall not be considered for stairways.

G. Storage Space and Machinery Rooms

Electrical equipment rooms, pump rooms, service rooms, storage space, and machinery rooms shall be designed for uniform LL of 250 psf, to be increased if storage or machinery loads so dictate. Fan rooms and battery rooms shall be designed for uniform loads of 350 psf.

H. Railings

Railings in station platforms, mezzanines and service walkways shall be designed in accordance with the Building Code.

I. Gratings

1. Gratings in areas that are subject to loading from vehicles shall be designed to carry HL-93 loading in accordance with AASHTO LRFD. Gratings in sidewalks and in areas protected from vehicular traffic shall be designed for a uniform LL of 300 psf.

2. Pedestrian assembly areas and platforms shall be designed for a Uniform LL of 125 psf.

3. Service and emergency walks shall be designed for a uniform LL of 85 psf of walkway area.

J. Seismic Design of Buildings

Building framing and components shall be designed to resist earthquake motions in accordance with the applicable codes of the Building Code. Seismic parameters shall be as prescribed by the Code or site-specific recommendations in the RTD Geotechnical Engineering Report.

9.4 AERIAL STATION PLATFORMS AND PEDESTRIAN BRIDGES

The following structures (but not limited to the following) included in the Project shall be designed in accordance with AASHTO LRFD, AASHTO Seismic Guide Specs, and HDOT Code when the structure participates in loads carried by the rail guideway girders, or in accordance with the Building Code when it does not.

A. Aerial station platforms

B. Pedestrian bridges and ramps/access

C. Mezzanines

9.4.2 Pedestrian Area Live Load

Pedestrian ramps, pedestrian bridges, mezzanines, and other pedestrian areas shall be designed for a uniform LL of 100 psf. Station platform areas shall be designed for a uniform LL of 125 psf. Pedestrian loads shall not be subject to a dynamic load allowance.

9.4.3 Vibration Criteria for Structures Supporting Pedestrian Traffic Only

To avoid the possibility of resonant vibrations induced by pedestrian traffic, the natural frequency of the unloaded structure shall be not less than 3.0 hertz. To avoid vibrations that might be objectionable to patrons, the calculated live load deflection, in inches, shall be limited to 1/500 of the span length.

9.4.4 Seismic Design

Station platforms, pedestrian ramps, pedestrian bridges, and mezzanines shall be designed to resist earthquake motions in accordance with the applicable Building Code or AASHTO LRFD, whichever is stricter. Seismic parameters shall be as prescribed by the above or site-specific parameters provided by the project geotechnical engineer.

9.5 MATERIAL DESIGN REQUIREMENTS AND CRITERIA

9.5.1 Reinforced and Prestressed Concrete Design

A. Minimum material properties: For all above ground reinforced concrete cast-in place structures, including columns, cap beams, and superstructure for aerial structures and bridges, columns, beams, slabs, foundations, and walls for the buildings: f'c = 4000 psi minimum.

B. For all cast in place drilled shaft foundations: f'c = 4500 psi minimum.

1. Mix design shall account for construction method, reinforcement clear space openings, and estimated time of placement.
2. Maximum 3/8-inch aggregate shall be used and rebar minimum clear spacing 5 inches unless it is demonstrated that drilled shaft reinforcing cage clear space opening of at least 10 times the maximum size aggregate is maintained.
3. No accelerants shall be permitted.
4. Temperature monitoring of trial and test shafts shall be performed at three locations within the shafts to establish heat of hydration development within the as-placed shaft trial mix concrete. The data acquisition system shall be capable of acquiring, storing, printing, and downloading [archiving] data to a computer. Temperature sensors shall be in the upper 20 feet and top and bottom of the middle third as measured along the length of the shaft. For purposes of temperature monitoring, the shaft diameter groupings shall be
    a. Under 8 feet
    b. 8 feet to 10 feet, inclusive
    c. 10 feet or greater up 14 feet
    d. Greater than 14 feet
5. Type-IV or Type-II (moderate heat) cement may be used in lieu of temperature monitoring.
6. Supplementary cementitious materials if used shall be fly ash and natural pozzolan, excepting Class-C fly ash, which is prohibited.
7. Mix design shall address the workability requirements for drilled shaft concrete over a period of time exceeding expected duration of the pour. Workability of shaft concrete shall be ensured over the expected duration of pours such that slump

measured at expected duration of pour plus 2 hours shall not be less than 6 inches. Duration of estimated pours shall take into account travel and any stand-by times and be based on substantiated placement production rates.

8. Once a mix design has been approved, it shall not be changed without substantiation as described above.

C. For prestressed concrete: f'c = 6000 psi minimum.

D. For all building foundations, floor slabs, pits, and other miscellaneous foundations at yards and shops; miscellaneous foundations other than those specified; and station platform foundations: f'c = 3000 psi minimum.

E. In certain cases, strengths of concrete other than those specified above might be required. These cases will be as recommended by the Designer and accepted by RTD.

F. Reinforcing steel: Bar reinforcement shall conform to AASHTO M 31 for billet-steel bars or ASTM A706 for low-alloy steel bars and the following minimum requirements:

1. Bars shall be deformed type.

2. Bars shall be Grade 40 or, for ASTM A615/A706 bars or when specified for AASHTO M 31 bars, Grade 60.

G. Prestressing steel: Stress relieved steel strand ASTM A416 (AASHTO M 203) (low relaxation), high strength steel bar ASTM A722 (AASHTO M 275).

9.5.2 Structural Steel Design

A. Structural steel channels, angles, MC shapes: ASTM A36 or ASTM A50.

B. Structural steel W shapes for building frame: ASTM A992.

C. Structural steel tube: ASTM A500 Gr B.

D. Structural steel pipe: ASTM A53 Gr B.

E. For uses requiring higher steel strengths or where economically justifiable: ASTM A242, A441, A514, A572, A588.

F. Structural steel and composite steel-concrete flexural members for aerial structures shall conform to the requirements of AASHTO LRFD.

G. The requirements governing LL deflections and structure deformations and settlements as outlined for reinforced and prestressed concrete design also apply to structural steel design.

H. Bolts: ASTM A325, unless otherwise shown.

I. Refer to AISC Manual of Steel Construction, Load and Resistance and Factor Design, Third Edition, Specification for Structural Joints Using ASTM A325 or A490 Bolts for use of bolts in snug-tightened, pretensioned, and slip critical joint applications.

J. Shop connections as detailed by the Designer shall be welded unless otherwise directed by RTD. Weld in accordance with the current code or specifications of the AWS, as applicable.

9.6 GEOTECHNICAL

9.6.1 Definitions

A. *Project geotechnical engineer* is defined herein by procurement method.

1. *Design-build (D-B):* Design-builder's engineer of record's lead geotechnical engineer who shall be a licensed professional engineer (civil or structural) as defined by the State of Hawaii Department of Commerce and Consumer Affairs (DCCA) and who shall be in responsible charge of all geotechnical work and who shall affix his stamp and seal on all project geotechnical reports. Reports shall be subject to RTD review and acceptance.

2. *Design-bid-build (D-B-B):* Lead geotechnical engineer who shall be a licensed professional engineer (civil or structural) as defined by DCCA and who shall affix his stamp and seal on all project geotechnical reports and recommendations prepared for RTD either directly or indirectly as an employee of the engineer of record or as a subconsultant to the engineer of record. Reports and recommendations shall be subject to RTD review and approval.

3. Lead geotechnical engineer shall have at least ten years experience in design of foundations for bridges or aerial guideways of similar size, type, and loading.

B. *Site* is defined per AASHTO LRFD Section 10.5.5.2.3: "A site shall be defined as a project site, or portion of it, where the subsurface conditions can be characterized as geologically similar in terms of subsurface stratification, i.e., sequence, thickness, and geologic history of strata, the engineering properties of the strata and the groundwater conditions." This definition is modified herein to read "contiguous portion" and not exceeding 5,000 feet in length.

C. *Dry Construction* for drilled shafts is defined herein as the excavation condition and concrete placement method wherein the bottom of shaft may be visually inspected prior to placement of concrete and where water depth at the bottom of the shaft is not more than 3 inches at the start of concrete placement and where water accumulation in the bottom of the shaft is not greater than 12 inches per hour when no water pumping is permitted.

D. *Wet Construction* for drilled shafts is defined herein as condition not qualifying as dry construction, requiring excavation and concrete placement through water or slurry, whether intended for excavation stabilization or result of naturally occurring hydrogeologic conditions.

E. *Non-redundant drilled shaft foundation* is defined herein as foundations consisting of three or fewer shafts per guideway bent or pier or those shafts deemed non-redundant per AASHTO LRFD Section 1.3.4.

F. *Deep foundations* as used herein are defined to include drilled shafts, driven piles, micro-piles, and other foundation types deriving their principal support from embedment into the subsurface and where embedment depth exceeds minimum element dimension.

G. *Shallow foundations* as used herein are generally footings for which capacity is derived principally from its bearing at shallow depth below existing or final ground surface adjacent to the foundation, e.g. embedment depth generally less than foundation width or length.

Reference AASHTO LRFD Section 10.2 for additional foundations-specific definitions.

9.6.2 Geotechnical Planning Report

Within 90 days following NTP, the project geotechnical engineer shall prepare a Geotechnical Planning Report (GPR) and submit the GPR to the RTD for review and acceptance (D-B contract) or approval (D-B-B contract) prior to the start of field investigations.

The GPR shall define the engineering and design approach that the project geotechnical engineer will follow to develop the necessary geotechnical information for the Project in accordance with the requirements of these design criteria. The GPR will address all aspects of the required geotechnical effort and foundation design and analysis, including, but not limited to, the following:

A. Succinct description of the structural and civil project components that the geotechnical work scope addresses.

B. Methods proposed to execute any of the identified subsurface investigation and data needs and develop sufficient data, including laboratory and field tests, for the analyses per AASHTO LRFD Sections 10.4.3 and 10.4.5. Demonstrate that the investigation meets or exceeds the requirements of the Contract.

C. Proposed methods of geotechnical analyses and construction:

   1. Proposed geotechnical analyses for the identified structural and civil components, including software to be used.

   2. Proposed construction methods for drilled shaft and pile foundations.

D. Coordination with structural engineer.

E. Proposed format of geotechnical reports and topical outline.

F. Proposed deflection and settlement criteria to be used for design of deep foundations.

9.6.3 Geotechnical Investigations

Subsurface investigations shall be conducted in accordance with AASHTO LRFD Section 10.4.2 (Subsurface Exploration) and FHWA HI-97-021 (Subsurface Investigations-Geotechnical Site Characterization). Frequency of investigations shall be sufficient for the design and construction planned but not less than minimums set forth in AASHTO LRFD Table 10.4.2-1 and specified herein. Geotechnical investigations completed for the Project as well as other existing geotechnical information are made available for the project geotechnical engineer's use. These completed investigations are included in the Geotechnical Data Report.

Field investigation locations for deep foundations completed by the City shall be deemed acceptable when located within 20 feet of the final foundation location as measured from the center line of the foundation(s) where foundations derive less than 25% of their support from end bearing on or in rock, coralline, or coralline detritus formations. Where foundations derive 25% or more of their support on or in rock, coralline or coralline detritus formations, all subsurface investigation holes whether completed by the City or new, shall be located within the footprint of each drilled shaft, or within the footprint of the foundation of other types of foundations.

Any additional geotechnical investigations required to complete the work in accordance with the criteria presented herein and with the Standard Specification 02 32 00 - Geotechnical Investigations shall be located within foundation plan limits. Furthermore at bents where multiple drilled shafts are used to support the pier or column, geotechnical investigations shall be performed at each drilled shaft locations where the drilled shafts derive 25% or more of their support on or in rock, coralline, or detritus formations.

9.6.3.1 Field Investigations

The project geotechnical engineer shall, prior to the start of any field investigations, submit a detailed plan addressing how the planned field investigations meet the requirements of the GPR. The locations of these investigations shall be shown on a site plan not smaller than 1 inch equal to 200 feet. The plan shall clearly state the types of equipment to be used, planned completion/ penetration depths, sampling types and intervals, any down hole testing planned, and completion details. In addition, the plan must address management of investigation, spoil material, maintenance of traffic requirements, environmental compliance requirement, and a time line for execution of the work, including permitting and utility clearances. Investigation methods shall conform to the recommendations of FHWA HI-97-021 and these criteria. Handling and storage of investigation derived samples shall be in accordance with the requirements Standard Specification Section 02 32 00 – Geotechnical Investigations.

9.6.3.2 Field and Laboratory Testing

The project geotechnical engineer shall, prior to the start of any field and laboratory testing, submit a detailed plan addressing how the planned testing meets the requirements of the GPR. Applicable testing methods and procedures shall be cited. Unless otherwise noted, all testing standards shall be in accordance with HDOT standards. In addition, the plan shall clearly state the name(s) and locations of the testing facility that will be used and any applicable certifications/accreditations. Testing facility shall have current accreditation by HDOT, AASHTO Materials Reference Laboratory (AMRL) or Navy for the specific laboratory tests to be performed.Laboratory testing shall meet the requirements of AASHTO LRFD Section 10.4.3 and Standard Specification 02 32 00-Geotechcnical Investigations.

9.6.4 Geotechnical Data Reports

Geotechnical reports or memoranda as detailed below, signed and sealed per the requirements of 9.6.1 above, shall be submitted to the City for review and acceptance (D-B contract) or approval (D-B-B contract). Reports to be based on FHWA ED-88-053 (Checklists and Guidelines For Review of Geotechnical Reports and Preliminary Plans and Specifications).

The project geotechnical engineer shall prepare signed and sealed per the requirements of 9.6.1 above, and submit to the City report(s) documenting the field investigations and all field and laboratory testing performed, explicitly noting the date, project limits or specific area represented, the report's intended purpose, and all field and laboratory data obtained. These investigation data, together with investigation data included in the Geotechnical Data Report, shall be the bases for the engineering analyses and geotechnical designs.

9.6.4.1 Interpretation, Analyses, and Recommendations

The Project Geotechnical Engineer shall prepare and submit to RTD a geotechnical report, which shall be based on the available subsurface information, and shall include at a minimum a discussion of the interpreted subsurface and ground water conditions, including but not limited to:

A. How RTD-provided geotechnical information is incorporated.

B. Evaluation of geotechnical conditions encountered.

C. Site subsurface characteristics, variation thereof, and rational or bases for selected engineering design properties. At a minimum, site characterization(s) shall include formation, location and thickness of soil and rock units, ground water conditions observed, including design profile, interpreted engineering properties for each soil and rock unit encountered, recommended design parameters for design of the foundations, and an assessment of geologic and seismic hazards. At a minimum engineering properties and design parameters to be addressed include but not limited to:

    1. Cohesion and adhesion,
    2. skin friction,
    3. end bearing,
    4. lateral earth pressures,
    5. soil or rock spring constants or horizontal modulus, and
    6. intermediate factors.

D. Site characterizations for seismic design, including bases for seismic design parameters if different from HDOT Code, site classification (AASHTO Seismic Guide Spec Section 3.4.2.1 or Building Code Section 1613.5.2), response spectra, and site-specific properties used for sites requiring site-specific evaluations under the governing code.

E. Definition of the extent [alignment station or area] that the characteristic site (as defined in this criteria) represents, and variations of engineering properties, if any.

F. Areas where foundation excavation will extend below first ground water, including discussions of ground water chemistry and the potential for ground water fluctuations whether seasonal or tidal, and artesian.

G. Discussion of how the engineering designs, design parameters, and analyses take construction means and methods into account.

H. Discussion of recommended resistance factors for design of structure foundations in accordance with requirements of HDOT Code and discussion of recommended factors of safety for structures or facilities where design is governed by the Building Code.

9.6.5 Geotechnical Designs

Project structures and improvements shall be designed so that imposed loadings do not exceed soil resistance while limiting deflections, as applicable, to prescribed maximums. Foundations supporting aerial guideways and transit rail retaining walls shall be designed in accordance with the requirements of AASHTO LRFD Chapter 10 and 11, and AASHTO Seismic Guide Spec. Foundations for buildings, retaining walls, and appurtenances not governed by this design criteria, shall be designed in accordance with Building Code Chapter 18 (Soils and Foundations). Presumptive load resistance values (i.e., maximum allowable bearing pressures and lateral resistance) shall not exceed the maximum values specified. Additionally, for aerial guideway designs a minimum of 50% of the bent locations within the specified reach or segment shall have been investigated and reported to the City in accordance with Geotechnical Investigations (listed above), prior to submittal of the design report required by the following subsection.

9.6.5.1 Deep Foundations

Design of deep foundations shall be based on project-specific information developed for the location and foundation type(s) planned. Soil and rock engineering properties shall be based on the results of field investigations as presented in the geotechnical report required by 9.6.4.1 above; use of presumptive values will not be allowed. Bottom clean out of drilled shafts constructed using the wet method shall be verified by Miniature Shaft Inspection Device® (MiniSID) or approved equal. Auger cast pile are not acceptable for support of aerial guideway.

Tops of deep foundations, including top of drilled shafts or pile caps where multiple shafts or piles are employed, shall be a minimum of 2 feet below lowest adjacent finished grade.

The upper 5 feet as measured from lowest adjacent grade shall be discounted in any axial and lateral load analyses to account for possible future excavations around the shaft or pile group.

Statnamic or APPLE type testing shall not be substituted for the specified pile capacity testing required herein.

Axial demands must account for down drag loads.

A. Drilled Shafts

Permanent steel casing shall be provided in areas and to depths where based upon subsurface investigation program the soil strength is anticipated to be 600 psf or less. Where permanent steel casing is used and is relied upon for structural capacity, itshall have a minimum wall thickness of 3/4 inch. Additionally, the design basis of the steel section shall be reduced to account for corrosion over the life of the structure based on actual soil and ground water conditions but not less than 1/8 inch; in lieu of a site specific corrosion study, a presumptive value of 1/4 inch shall be used. Steel casing shall not be considered for structural support in extremely aggressive environments.

Drilled shafts designed with their tips founded on coralline or coralline detritus formations shall not include end bearing capacity in the design. Drilled shafts designed with their tips founded on or within cobbles and boulders shall not include end bearing capacity in their design without a load test to substantiate field values. Base grouting, in accordance with the requirements of Specification Section 31 63 30 – Drilled Concrete Shaft Foundations, shall not be allowed without prior written consent of the City and where allowed shall not relieve contractor from any of the Contract requirements.

For guideway shafts greater than or equal to 5 feet in diameter, the drilled shafts shall be designed assuming the column is offset at the top of the shaft a minimum of 6 inches. Minimum concrete cover over reinforcing steel for drilled shafts shall be 6 inches.

Method shafts shall be performed on a minimum of one drilled shaft at any given Site but not less than one per 5,000 contiguous feet or portion thereof of aerial guideway alignment where subsurface conditions are defined as being similar (i.e., Site). Method shaft for each Site shall be completed and accepted prior to initiating load test shafts.

Load tests shall be performed on a minimum of one drilled shaft at any given Site but not less than one per 5,000 contiguous feet or portion thereof of aerial guideway alignment where subsurface conditions are defined as being similar (i.e., Site) in the Geotechnical Data Report. Load tests shall be performed on shafts of the same diameter, length, reinforcement and permanent casing as planned for the production drilled shafts and using the means and methods of the accepted method shaft test. Load tests for each Site shall be completed before starting any production shafts within that Site. Load tests shall not be performed on any permanent drilled shaft. Load tests shall be performed using the Osterberg load cell (O-Cell) test method.

B. Driven Piles

Driven piles founded on coralline or detritus formations shall not include end bearing capacity in the design, driven piles founded on or within cobbles and boulders shall not include end bearing capacity in their design without a load test to substantiate field values.

Geotechnical capacity of the pile size, length, and grouping shall be based on the design parameters reported in the geotechnical report specific to the Site or segment under consideration. Adjustments to reported engineering properties based on local experience of field load tests shall be explicitly noted and justification documented.

Wave Equation Analyses shall be performed prior to pile driving to verify that the pile can be driven to the required capacity and penetration depth at a reasonable driving resistance without excessive driving stresses.

Dynamic load tests with signal matching shall be performed, in accordance with ASTM D7383-08 Standard Test Methods for Axial Compressive Force Pulse (Rapid) Testing of Deep Foundations, on all test piles and on a minimum of 2 percent of production piles. Static load tests shall be performed in accordance with ASTM D1143/D1143-07e1

Standard Test Methods for Deep Foundations Under Static Axial Compressive Load on a minimum of one driven pile at any given Site but not less than one per 2,500 contiguous feet or portion thereof of aerial guideway alignment where subsurface conditions are defined as being similar (i.e., Site) in the geotechnical report.

C. Micropiles

Design of micropiles shall be in accordance with AASHTO LRFD Section 10.9 (Micropiles) and FHWA-SA-97-070 (Micropile Design and Construction Guidelines, June 2000).

End bearing resistance shall not be included in the design of micropiles.

Verification load tests shall be performed in accordance with ASTM D1143/D1143-07e1 Standard Test Methods for Deep Foundations Under Static Axial Compressive Load on a minimum of one micropile at any given Site but not less than one per 2,500 contiguous feet or portion thereof of aerial guideway alignment where subsurface conditions are defined as being similar (i.e., Site) in the geotechnical report. Verification load tests shall not be performed on any permanent micropiles.

Additional requirements bearing on micropile design considerations are presented in Standard Specification Section 31 63 33 – Drilled Micropiles, including proof testing.

9.6.5.2 Shallow Foundations and Miscellaneous Structures

A. Shallow Foundations

Per AASHTO LRFD Section 10.2 (Definitions): “Shallow Foundation— A foundation that derives its support by transferring load directly to the soil or rock at shallow depth.”

Design of shallow foundations, e.g., spread and strip footings, shall be based on project-specific information developed for the location(s) and foundation type(s) planned. Soil and rock engineering properties shall be based on the results of field investigations as presented in thegeotechnical report; use of presumptive values will not be allowed. Designs of shallow foundations supporting rail structures or attached appurtenances shall be as required in AASHTO LRFD Section 10.6) and in accordance with FHWA-SA-02-054 (Geotechnical Engineering Circular No. 6 Shallow Foundations)). Shallow foundations for support of structures under the purview of the Building Code, buildings not directly supported off the aerial guideway, shall be designed in conformance with the requirements of Building Code Section 1805 (Footings and Foundations).

Shallow foundations shall have a minimum ground cover of 2 feet as measured from top of footing to finished grade. Support of aerial guideway on shallow foundations will not be permitted.

Geotechnical investigations for shallow foundations shall be in accordance with ASSHTO LRFD Section 10.4.2 Subsurface Exploration and Table 10.4.2-1 therein.

B. Miscellaneous Structure Foundations

Design of shallow foundations for miscellaneous structures shall be in accordance with the above requirements for shallow foundations, excepting that presumptive values may be used. These include, but are not limited to miscellaneous structures such as light standards, signs, retaining walls less than 10 feet in height and not supporting any structures, and other such lightly loaded and uninhabited structures.

9.6.6 Settlement and Deflection

Allowable foundation settlements and lateral deflections (deformations), except as prescribed herein, shall be established by the project structural engineer in consultation with the project geotechnical engineer.

9.6.6.1 Deep Foundations

Settlement of deep foundations (i.e., drilled shafts or driven piles) shall be limited to no more than 1/2 inch total vertical deflection as measured at the pile head or top of pier cap after placement of the pier column. Total settlement measured after placement of the guideway girder shall be limited to not more than 1 1/2 inches. Differential settlement between adjacent bents spaced not less than 100 feet apart shall be limited to no more than 1 inch; this maximum decreases proportionately for lesser bent spacing and increases by ½ inch per 100 feet for bent spacing exceeding 100 feet.

Lateral deflection limitations for design of deep foundations for non-seismic loading shall be determined by the project structural engineer and systems engineer in consultation with project geotechnical engineer. Deflections of deep foundations under extreme or earthquake loadings shall be established by the project structural and geotechnical engineers but not greater than the deflection and rotation which would result in a deflection of 18 inches at the top of rail.

9.6.6.2 Shallow Foundations

Shallow foundations shall be designed to limit total settlement to no more than 1 inch and differential settlements between adjacent footings to no more than 1/2 inch and differential settlement across the length or width of a footing to an angular distortion of not more than 1:750.

9.7 STATIONS

Design requirements for transit stations shall be in accordance with the criteria and bases defined herein. Station design shall be coordinated with aerial guideway design and performance. Station designs must include and account for the deflections and settlement of the separately designed and constructed aerial guideway.

9.8 RETAINING WALLS

Retaining walls shall be designed in accordance with AASHTO LRFD Section 11. Reinforcing elements for mechanically stabilized earth and other such proprietary retaining walls shall be of non-metallic type.

9.9 EXCAVATION SUPPORT STRUCTURES

Excavation support structures shall be designed and constructed to resist the loads and displacements caused by *in-situ* ground and water pressures, applicable roadway and structure surcharge loads,construction surcharges, and the installation and removal of ground support elements. Excavation support structures shall be designed and constructed in accordance withthe Standard Specifications.

END OF CHAPTER

Honolulu High-Capacity Transit Corridor Project

(Project)

DESIGN CRITERIA

CHAPTER 10

ARCHITECTURE

May 22, 2009

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10.0 ARCHITECTURE

10.1 GENERAL

10.1.1 Introduction

This Chapter of the criteria pertains to all stations and station sites. Elements discussed in this Chapter include area requirements, design of platforms, amenities, platform access, guidelines for the selection of materials, general guidelines for use in the design of bus facilities, kiss-and-ride and park-and-ride facilities, stations, and ancillary facilities. It includes space requirements, materials and finishes, and standards for planning and construction.

10.1.2 Goals

The design of all elements should anticipate a 50-year design service life that will minimize future replacement and maintenance. System facilities should be consistent with the Project's sustainability goals and objectives.

Considering the anticipated growth and longevity of the system, careful consideration must be given to station compatibility with proposed future development in the neighborhood of each station.

The *Design Language Pattern Book* shall be used as a guide for the station design.

The Station Designer should become familiar with the general aspects of the entire system in order to determine how the Designer's individual project relates to the whole. It is essential that a consistency of space design and equipment layout be maintained throughout the system for the convenience of the patrons. Operational and maintenance requirements must be considered so that each station functions with maximum economy and efficiency.

10.1.3 Reference Data

A. Applicable Codes and Standards

1. This section lists the codes, regulations, standards, and other architectural criteria to which the design of the Project shall conform. In the event that a condition exists that is not covered by the codes, regulations, and standards listed below, the RTD shall be notified for further determination. The basic goal of these codes and standards is to ensure the public welfare by providing project facilities that do not compromise the health and safety of the public or the users of the system.

2. The design of the stations shall comply with all Federal, State, and Local codes. These codes and standards shall in each instance be the most recent revision, amendment, or supplement adopted by Federal or State authorities or as administered by the City at the date of notice to proceed with the final design of each specific project, or as directed by the RTD.

3. According to the U.S. Department of Justice Code of Federal Regulations (28 CFR 36, Appendix A, Standards for Accessible Design), all transportation facilities constructed for the general public must be accessible and barrier-free. Related standards, including those of the Department of Transportation and of other Federal

and State government agencies having jurisdiction, shall be used in designing and constructing the system so that it is free of architectural or transportation barriers.

4. Unless specifically noted otherwise herein, the latest edition of the code, regulation and standard as amended by the local jurisdiction shall be used.

5. It is the responsibility of the Station Designer to ensure that all code requirements are met, whether or not they are cited here.

6. With the exception of the variances described herein, where the requirements of more than one code or standard are applicable, the more restrictive shall govern.

7. Codes, Regulations, and Standards

   a. Federal and State, latest editions

   b. Codes as administered by the City

   c. International Building Code (IBC) as amended by Federal and Local jurisdictions

   d. American National Standards Institute, Inc. (ANSI)

   e. ICC/ANSI 117.1-03

   f. Architectural Barriers Act (ABA) Accessibility Guidelines

   g. American with Disabilities Act Accessibility Guidelines (ADAAG)

   h. Accessibility Guidelines and USDOT standards and 49 CFR 37

   i. American Society of Testing and Materials (ASTM)

   j. American Society of Mechanical Engineers/ANSI Safety Code for Elevators and Escalators ANSI/ASME A17.1

   k. ASCE 7-88 Minimum Design Loads for Buildings and Other Structures

   l. NFPA 70, National Electric Code (NEC)

   m. NFPA 101, Life Safety Code

   n. NFPA 130, Standard of Fixed Guideway Transit and Passenger Rail Systems

   o. NFPA National Fire Codes (as applicable)

   p. Structural Welding Code: Steel, 13th Edition (AWS D1.1)

   q. Underwriters Laboratory, Inc. (UL)

   r. U.S. Department of Transportation (DOT) 49 CFR, Part 37, Transportation Services for Individuals with Disabilities

   s. Other Regulations and Applicable Documents

i. Americans with Disabilities Act (ADA)

ii. Architectural Barriers Act (ABA)

iii. Occupational Safety and Health Act (OSHA)

iv. American Public Transportation Association (APTA)—Rapid Transit Design Guidelines

v. U.S. Green Building Council LEED® Rating System for New Construction and Major Renovation

vi. U.S. Green Building Council LEED® Rating System for Neighborhood Design

B. Patronage Analysis

Patronage analysis studies use the latest projections of future employment, population, building development, and other activities in proximity to the system's stations to predict the ridership of the system, as well as each of its stations. These studies identify such fundamental factors as locations of trip origins and expected modes of access to the station that vary with the time of day and time of year.

The system's ridership projections, operational information, and the pertinent requirements of National Fire Protection Association (NFPA) 130 will be used to determine the size and number of station entrances, size of the platforms, number of fare devices, and the number of stairs, escalators, and emergency exits.

C. Design Aesthetics

Station Designers will be furnished a *Design Language Pattern Book* by the RTD that will be used to guide the design of the stations. Site-specific local characteristics at certain stations may yield unique design considerations that may be presented to the RTD for possible inclusion in the station designs where not addressed in the Pattern Book.

D. Prototype Station Designs

Prototype station design drawings will be furnished to the Station Designers by the RTD. These drawings will describe basic station configurations, including platform, concourse, and ancillary and entrance plaza concepts and will serve as a basis for the Station Designers to prepare the preliminary engineering and final design drawings.

E. Station Scope of Work

These documents outline the work of the Station Designer and include stages of design, submittals, budget, and schedules. This scope of work information also includes baseline drawing and mapping files, prototype station designs, station and station site programmatic data, the *Design Language Pattern Book*, and the Compendium of Design Criteria.

F. Utility Locations

Utility drawings for the various sites will be made available by the RTD.

G. Other General Data

Master plans, urban renewal plans, and plans for specific future projects in the area of influence for a particular station should be reviewed for pertinent information that might influence site development and design possibilities. This contextual station planning data shall be provided to the Station Designers by the RTD in the form of the following reports and guidelines:

1. Station Area Interface and Access Report
2. Transit System Urban Design Guidelines
3. Archeological resources Technical Report
4. Cultural Resources Technical Report
5. Street Trees Technical Report
6. Sustainable Community Impact Report
7. Station Area Development Potential Report

H. Definitions

1. *Aerial Station:* A station in which the tracks and platform are located on an aerial structure.
2. *Artist:* An individual or team contracted to produce artwork that is integrated with the station architecture.
3. *Aerial Structures*: A structure, other than a culvert, which carries transit tracks and spans above land or water surfaces.
4. *Architect:* Individual or firm responsible for station architectural design.
5. *CPTED:* Crime Prevention through Environmental Design.
6. *Conceptual Drawings:* Site-specific general plans using the prototype designs as required to fully describe each facility to a 10 percent level of design.
7. *Concourse:* The public area station level between the station entrances and the platform. The concourse may include both free and paid areas.
8. *Directive Drawings:* Drawings defining the arrangement or configuration of specific components of transit facilities (see also Prototype Designs).
9. *Fare Barrier:* The separation between the paid area and the free area consisting of fare collection gates and other devices.

10. *Final Design:* Construction drawings and specifications prepared by the Station Designers, approved by the Rapid Transit Division (RTD), and ready for issuance to construction contractors for bidding.

11. *Free Area:* The public space within the station that the passengers use before entering or after exiting the Paid Area.

12. *GEC:* General Engineering Consultant.

13. *Kiss-and-Ride:* A short-term parking area that includes passenger drop-off and pick-up areas, short-term off-peak parking, and taxi-waiting areas.

14. *Off-Street Entrance:* An entrance to a station where the point of access to the vertical circulation elements is located within an adjacent property.

15. *Paid Area*: The space within a station that passengers use after paying a fare.

16. *Pattern Book:* Definition of key historic and cultural elements of the Project's Basis of Design.

17. *Platform:* The area of a station that is directly adjacent to the tracks where trains stop to load and unload passengers.

18. *Park-and-Ride:* An area designated for long-term parking, most often all-day parking of motor vehicles used by transit patrons.

19. *Preliminary Engineering:* That portion of the total Project Design that identifies all essential elements of the stations and their sites, all ancillary facilities, and the full extent of the fixed-guideway structures to a 30-percent level of design.

20. *Prototype Designs:* The designs that define the spatial and functional requirements for different types of stations and fixed facilities. Directive Drawings will be used to illustrate Prototype Designs.

21. *Platform Loading:* The area or areas on a platform through which passengers enter and exit. Examples would include center loading, end loading, quarter loading, and third loading.

22. *Platform Types:* Center Platform—A platform between tracks that gives patrons access to trains arriving from either direction. Side Platform—A platform adjacent to a track that gives patrons access to trains traveling in only one direction.

23. *Operation Control Center (OCC):* That portion of the Central Control Facility where all train control and communications systems, controls, displays, and monitors are housed. It is also the area where all emergency and malfunction alarms are sounded and recorded, and from which the operating controllers can intervene and manage system operations, the structure, the parking area, and office and other fixed facilities related to the management and operation of the rail system.

24. *Queuing Area:* Area of a station where pedestrians may line up (queue) without interrupted passenger flow or cross movements.

25. *RTD:* Rapid Transit Division—A division of the Department of Transportation Services, City and County of Honolulu (City), Hawaii.

26. *Right-of-Way (ROW):* All land used by RTD for the development and operation of the Project.

27. *Station Designers:* The architectural and engineering firms responsible for preparing preliminary engineering and/or final design documents for the Project stations and other Project facilities.

28. *Standard Drawings:* Drawings defining standard arrangements and details that will be repetitively used throughout the Project and incorporated into the Station Designers' preliminary engineering and final design drawings.

29. *Station:* All areas and improvements within the boundaries of the station site, including entrances, concourses, platforms, and ancillary spaces.

30. *Station Site:* Land owned by the transit property that is used for the station, the immediate guideway, and all on-site provisions constructed for vehicular and pedestrian access and egress.

31. *Station Design Scope of Work:* A definition of the work to be performed by the Station Designer, including milestone submittals, budget, and schedules.

32. *Top-of-Rail Profile:* The profile line representing the elevation of the top of running surface rail.

33. *Train:* Single or multiple vehicles combined to operate as one unit.

34. *Trainway/Trackway:* That portion of a station or structure on/through which the trains run.

35. *TOD:* Transit-oriented development.

10.1.4 Related System Interface

For additional design criteria relating to this chapter, refer to Chapter 3, Environmental Considerations, Chapter 4, Track Alignment and Vehicle Clearances, Chapter 6, Civil, Chapter 7, Traffic, Chapter 8, Utilities, Chapter 11, Landscape Architecture, Chapter 12, Passenger Vehicles, Chapter 15, Communications and Control, Chapter 19, Facilities Mechanical, Chapter 20, Facilities Electrical, and Chapter 25, System Safety and Security.

10.2 STATION SITE DESIGN

10.2.1 Introduction

The location and boundaries of station sites, adjacent street improvements, and each station location shall be established by the RTD or its designee. The site layouts consider the relationships of the station facilities to the surrounding area and the pedestrian and vehicular circulation patterns required for safe and effective access to the transit system.

10.2.2 Basic Goals

The basic goal of site design is to ensure that each station satisfies operational demands and is well integrated into the existing urban fabric and the communities that the stations serve.

Site design should respond to the unique climate of Honolulu and adhere to the sustainable design principles established for the system. Station site design shall be of high quality and achieve cost effectiveness while successfully satisfying the various functional and aesthetic requirements.

10.2.3 Priority Access Modes

A. General

A hierarchy of access modes has been established based on the importance of the access mode, the convenience of access, and the proximity to the station entrance(s) from the various modes. Priority is given the following modes in order of importance:

1. Pedestrians: Pedestrian access to the stations, including accessible routes, shall be given first priority for reasons of safety.

2. Bicycles: As a non-motorized mode of access, bicycle access will be given priority over motorized vehicular access modes.

3. TheHandi-Vans: Turn-out spaces shall be provided immediately adjacent to the station entrances.

4. TheBuses: Feeder buses will play an important role in intermodal connections and the overall success of the system. TheBuses will be given priority as a vehicular mode of access. Bus access to and from the site shall not be compromised by other modes of transportation.

5. Kiss-and-Ride (including taxis): Kiss-and-Ride spaces allow high volumes of patrons to access stations in short periods of time. The kiss-and-ride area will include taxis and drop-off and pick-up spaces. These spaces shall be configured for short-term parking in off-peak hours of operation. Kiss-and-ride spaces should be as close to the station entrance as possible without interfering with bus facilities and be located so as to provide incentive not to stop on adjacent public streets.

6. Park-and-Ride (including motorcycles): Park-and-ride, or long-term parking, while not the highest priority, is still necessary for the success of transit systems. Whether at-grade or within a structure, such parking shall be located at a greater distance from the station entrance than other modes where site conditions allow. Whenever possible, the walking distance from the station entrance to the most remote parking space should not exceed one-quarter of a mile measured along the actual pedestrian travel route.

10.2.4 Pedestrian Access

A. General

Pedestrian access will vary from one site to another depending on location and function of the station. In all cases, however, pedestrian access to the station should be as direct and safe as possible, and shall be accessible in accordance with ADAAG.

B. Station Access/Egress Routes

1. Adequate pedestrian circulation routes shall be provided with an emphasis on avoiding pedestrian/vehicular conflicts, enabling good visibility to each station entrance, and complemented by distinct and clear graphic signage.

2. Pedestrian paths shall be as direct as possible from the surrounding street system or from any point within the station site.

3. Station entrances should be located at or in close proximity to signalized crosswalks.

10.2.5 Bicycle Access

A. Provisions shall be made for access to and from stations by bicycle, including their storage at station sites.

B. Bicycle racks shall be placed at the station plaza near the station entrance where public visual surveillance is possible and/or where closed circuit television (CCTV) monitoring is present.

C. The total number of bicycle parking spaces per station should be at a minimum one space for every one thousand (1,000) predicted daily rail transit boarding for that station, based on the greater number provided in any current or revised Environment Impact Statement (EIS), as space permits.

1. The minimum total number of bicycle parking spaces at any transit station shall be 20.

2. Racks should allow securing front wheel and frame with high security locks.

3. In the design of each station, space for the required total bicycle parking should be provided.

10.2.6 TheHandi-Vans and TheBus

A. General

TheBuses and TheHandi-Vans shall be given priority for vehicular access in terms of their proximity to station entrance(s).

B. Bus Shelters

1. Bus waiting areas at transit centers shall be covered by canopies and shall be equipped with ample seating.

2. Bus shelters at bus transit centers adjacent to the station area should be consistent with the architecture of the stations.

10.2.7 Park-and-Ride Facilities

A. General

1. Park-and-Ride is primarily a suburban transit station activity that enables long-term parking, including all-day usage. Pedestrian safety and security is of the highest priority in the design of these facilities.

2. Park-and-ride facilities shall be provided at designated stations. The amount of parking spaces at a particular station will depend upon the demand for park-and-ride spaces, the ability of the local street system to accommodate a station site's vehicular access and egress requirements, as well as the determined appropriateness of a park-and-ride facility at specific stations from a land use standpoint as regulated by local zoning codes.

3. Park-and-ride facilities shall be designed to provide visual connections that are as direct as possible to the station entrance(s) (see Item 5 below).

4. Parking facilities may be at-grade with provision for structured parking in the future, or structured parking with expansion capability.

5. The ability to have paid parking at or near the parking stalls or upon exit must be designed into all park-and-ride facilities. Provisions for pay-on-exit capability shall include space that will enable the installation of booths and/or gates at both the facility's entry and exit roadways. The space provided for the booths and exits shall be located such that car queuing is contained within the park-and-ride site so as to not disrupt vehicular flow along adjacent roadways or within the station site itself.

6. The facilities for park-and-ride should be designed for self-parking.

B. Parking Structures

1. Pedestrian safety and security within parking structures shall be of the highest priority in the design of these facilities.

2. Parking structures shall provide standard parking spaces, compact parking spaces if required by local regulations, accessible parking spaces, and spaces for motorcycles. It may be determined that parking structures shall incorporate provisions for vans and/or for kiss-and-ride facilities.

3. Space shall be provided for elevators in the event the parking structures exceed three levels (two levels above-grade). Elevator locations shall be as close as practical to the station entrance.

4. On site access roadways to parking structures shall be kept to a minimum, thereby enabling the clearest, most direct access circulation to the garage.

5. Interior circulation within parking structures shall be intuitively clear, include two-way traffic, double-loaded aisles, 90-degree parking for maximum efficiency, and a minimum of dead-end parking areas.

6. Driving aisles shall be oriented toward the primary vertical circulation elements, which shall in-turn be located close to the station entrance.

7. For maximum efficiency, circulation ramps shall be used for both parking and the vertical circulation of vehicles. The maximum ramp slope shall be 4 percent. Greater slopes of up to 5 percent will require special RTD approval.

8. If special circumstances preclude an on-ramp parking design, separate ramps (or spiral ramps) may be employed with preferred slopes of 8 percent or less and an absolute maximum of 12 percent. Slopes greater than 8 percent will require special RTD approval.

9. The ability to have paid parking must be designed into all parking structures. Provisions for pay-on-exit capability shall include space that will enable the installation of booths and/or gates at both the facility's entry and exit roadways. The space provided for the booths and exits shall be located such that car queuing is contained within the parking structure and, to a reduced extent, its off-street access roadways. The goal is to minimally disrupt the station site's internal roadways and not disrupt vehicular flow along adjacent roadways.

10. Parking structures shall conform to the following:

    a. Minimum vehicular clearance height 8 feet 0 inches, with an absolute clear height of 7 feet 8 inches anywhere in the structure. If the parking structure or areas thereof are designated to be van accessible, the minimum vehicular clearance height shall be 9 feet 8 inches anywhere in the structure.

    b. Ramp Grades

        i. Parking on ramp: 4 percent desirable, 5 percent maximum

        ii. No parking on ramp: 5 percent desirable, 12 percent maximum

    c. Parking Structure Spaces: 8.5 foot x 18 foot stall with 24-foot driving aisle

    d. Width of entrance/exit lanes: 12 feet

    e. Aisle turning radii: 16 feet inside, 30 feet outside

    f. Curb height: 6 inches

    g. Electric car charging stations: two stations per parking structure

11. Pedestrian Circulation

    a. Weather protection shall be provided between the parking structure and the station entrance(s).

    b. Travel pathways from the parking structure to the station entrance(s) shall be direct, clearly defined, and well lit.

c. Pedestrian movements shall be directed along driving aisles to the primary vertical circulation elements.

d. Where pedestrians must cross traffic within the parking structure, clearly defined crosswalks shall be provided giving right-of-way to pedestrians.

12. Stairways and Elevators

a. There shall be one primary stairway/elevator in each parking structure located closest to the station entrance. Appropriately sized vestibules shall be included adjacent to the stairway/elevator entrances.

b. To minimize the use of elevators by the disabled, as well as to shorten their travel distance to the station entrance, the accessible parking spaces shall be located at the ground level or at the station entrance level if it is not at grade.

c. A minimum of two elevators shall be provided at each elevator bank.

d. Primary stairways shall be designed as fire stairs, with width, height, treads, risers, ventilation, and lighting in accordance with the governing building code.

e. Primary stairways shall be designed to accommodate the anticipated traffic from the station entrance. Additional fire stairs shall be spaced and located within parking structures as required by the governing building code.

13. Structural Requirements

a. Parking structures shall be constructed of cast-in-place and/or pre-cast concrete.

b. Parking structures shall be designed in accordance with criteria for an open parking structure as defined in the most current, approved IBC with local jurisdictional amendments, and shall be considered an external exposure structure.

c. The structural bay for double-loaded spaces shall be 24 feet x 62 feet nominal, yielding a column-free parking bay.

d. Parapets should be as open as possible to promote good sight distances, security, and wayfinding; be designed to discourage climbing by pedestrians; and be aesthetically pleasing and integrated visually, functionally, and in the selection of materials. Parapets shall not be designed to receive vehicle impact. That function shall be achieved with a guard rail designed to withstand vehicle impact, placed between the facing panels and the vehicles.

10.2.8 Facilities for the Elderly and Disabled

A. General

1. These provisions are intended to make all station sites and facilities used by the public accessible to and functional for the disabled and elderly.

2. Parking spaces as close as practical to the station entrance should be set aside and identified in the park-and-ride area for use by individuals with physical disabilities.

B. Parking Structures

1. Accessible parking spaces shall be located as near as practical to a primary entrance to a facility (building or boarding platform). The space shall be located so that a person with a disability does not have to wheel or walk behind parked cars other than his or her own. Pedestrian pathways shall be provided so as to ensure an accessible path from each such parking space to the facility.

2. When parking is provided for patrons, employees, or visitors, the minimum number of accessible spaces required is as shown in Table 10-1.

Table 10-1: Number of Accessible Parking Spaces

Minimum Total Number of Parking Spaces	Spaces Required
1 to 25	1
26 to 50	2
51 to 75	3
76 to 100	4
101 to 150	5
151 to 200	6
201 to 300	7
301 to 400	8
401 to 500	9
501 to 1000	2 percent of total
1,001 or more	20 plus 1 for each 100 over

C. Walkways

1. Ramps and curb cuts shall be provided as required to provide safe and convenient circulation by the physically disabled to and from the station.

10.3 STATIONS

10.3.1 Introduction

Much of the success of the Project will depend on the attractiveness and efficiency of the individual stations. The system and its stations should provide a means of transporting people that is safe, convenient, pleasant, and efficient. The station designs should be of the highest quality so that they attract riders and be lasting sources of civic pride for the City.

10.3.2 Basic Design Goals

A. Embody Honolulu and Hawaii's rich cultural heritage in the physical form of the system's stations and support facilities.

B. Provide a functional identity for the system as a whole through the use of standard elements that will enhance wayfinding and ease-of-use for patrons, while also improving cost-effectiveness.

C. Encourage station designs that are context-sensitive, functionally integrated, and culturally expressive of their specific locations.

D. Incorporate the principles and practices of sustainability in the design of all facilities.

E. Ensure the safety and security of all passengers.

10.3.3 Configuration

A. Station Accessibility

The station design shall comply with relevant accessibility standards, including those of the ADA and ABA. All accessible entrances shall, to the maximum extent practicable, coincide with those used by the majority of the general public. Where the circulation path is different, signage complying with ADAAG shall be provided to indicate direction and identify the accessible entrances and routes.

B. Patron Circulation

The majority of transit passengers will be familiar with the process of entering and using the system. However, by using identical or similar entry and concourse and platform configurations, all passengers, regular users, newcomers, tourists, the elderly, and the physically handicapped will find the system user-friendly and inviting.

The following basic principles should be considered in planning station circulation:

1. Stations shall be designed to enable passengers to maintain a clear understanding of their location along the station entry, circulation, waiting, and exiting sequences that is enabled by clarity of design and a repetition of functional layouts from station to station.
2. People will tolerate longer delays in entering than in exiting stations. Therefore, exiting routes and their configurations must be apparent and easily used for both normal everyday use as well as emergency conditions.
3. People tend to keep to the right, and for that reason, right-hand flows are recommended, although not mandatory.
4. Cross-flow of passengers is undesirable and is to be avoided where possible.
5. Station designs shall comply with CPTED principles. Dead-ends and hidden recesses shall be avoided wherever possible.

C. Queuing Distance Requirements

Queuing distances shall be provided at all stations to promote safety and enable ease of circulation. Adequate space shall be provided around ticket vending machines and fare collection machines to allow patrons to buy their tickets and pass through without undue .crowding. See Table 10-2 for minimum queuing distance requirements.

Table 10-2: Minimum Queuing Distance Requirements*

Feature	Queuing Distance
Fare collection machines	15 feet 0 inches
Ticket vending machines	10 feet 0 inches when facing wall or similar obstruction 6 feet 0 inches when adjoining another queue space
Stairways	15 feet 0 inches
Escalators	20 feet 0 inches when facing wall or other similar obstructions 15 feet 0 inches when adjoining another queue space
(Two devices) Stair/escalator	15 feet 0 inches
(Four devices) Stair/escalator	25 feet 0 inches
Elevator	10 feet 0 inches

In situations where a stair or escalator faces a stair or escalator, the minimum clear space between them shall be the sum of that required by each less 25% (two devices = 15 + 15 - 25% = 22 feet 6 inches).
Where an elevator faces a stair or escalator, the minimum clear space between each device shall be the sum of that required by each less 25% (two devices = 15 + 8 - 25% = 1 foot 3 inches).
Where an elevator faces an elevator, the minimum clear space between the two shall be 15 feet 0 inches.
** Distances are measured as follows:*

- *From the face or leading edge of ticket vending machines and fare collection machines to any obstruction or vertical circulation element.*
- *From the leading edge of a stairway handrail to any obstruction or vertical circulation element.*
- *From the leading edge of an escalator balustrade to any obstruction or vertical circulation element.*
- *From the face of an elevator enclosure to any obstruction or vertical circulation element.*

10.3.4 Concourse

A. General

When included in a station's design, a concourse functions as a transition level between ground-level entrances and the platform(s) above. The concourse may provide space for various functions, including fare collection equipment, telephones, map cases, ash/trash receptacles, and other patron amenities.

B. Fare Vending and Fare Collection Arrays

All stations shall incorporate provisions for the inclusion of fare vending machines in number and size as determined by the ancillary space program.

The fare vending system shall be self-service and use exact change, tokens, transfers, or a pass. The layout of the fare vending machines shall be arranged so that the equipment can be used easily and quickly.

Although an honor system of fare collection will be used initially, all station entrances (or concourses when so stipulated by RTD or its designee) shall be sized and configured to accept the installation of fare collection arrays, either initially or in the future.

RTD shall determine the required number of fare collection machines and aisles for each station based on two key factors: station peak loading requirements and platform clearance under emergency exiting conditions. Platform clearance calculations shall include a determination of the number of fare collection array aisles that will ensure exiting passengers will have unimpeded flow to and through the fare collection array without the danger of passenger back-ups.

All fare collection arrays shall be sized by RTD to include a spare aisle, a service gate, and at least one accessible fare gate aisle, all in addition to the number of standard fare gates.

The fare collection array will separate the free area from the paid area. This array shall prevent anyone from reaching the paid area without passing through a fare gate, or leaving the paid area without passing through a controlled exit gate, except in certain instances through the service gate. Barriers between paid and free areas should be designed to provide appropriate physical separation without excessive visual emphasis on security.

C. Vertical Clearances

In all concourse areas, the minimum overhead clearance to obstructions shall be 11 feet above the finished floor. However, where a concourse crosses under the guideway structure, this overhead clearance dimension can be reduced to 7 feet 6 inches to reduce the station's overall height.

10.3.5 Ancillary Space Program

Table 10-3 summarizes the station's ancillary space requirements.

Table 10-3: Station Ancillary Space Program (Based on Two Station Entrances)

Activity/Space	Quantity	Size	Area	Operational/ Locational Needs	Design Criteria	Notes
Train Control & Communications (TC&C)	1	25'x40'	1,000 SF	▪ Ground level ▪ Exterior access ▪ Central in station complex where possible	▪ 6'x 8' out-swinging access door ▪ 9' vertical clearance ▪ Conduit access to track w/bends not to exceed 180 degrees ▪ 10-ton AC unit	
Mechanical room for TC&C	1	10'x16'	160 SF	▪ Adjacent to TC&C ▪ Can be upper level	▪ Adjacent & accessible outdoor condensing unit w/secure enclosure 2'-7" clear all sides ▪ 3'x 7' access door	▪ Condensing unit can be on roof
Fire sprinkler valve room	1	10'x10'	100 SF	▪ Can be upper level	▪ 3'x 7' access door	▪ Confirm with Fire/Life Safety requirements
Hydraulic elevator equipment room	2	10'x14'	140 SF	▪ Can be upper level ▪ For elevator to each platform	▪ Through wall AC unit ▪ 3'8"x 7' access door ▪ Provide for oil containment and recovery	
Escalator equipment	Per unit	NA	NA	▪ Built into escalator truss	▪ Natural/ mechanical ventilation	
Electrical room	1	6'x 8'	48 SF	▪ At entrance opposite from UPS/Electrical Room location ▪ Can be upper level	▪ 3'x 7' access door	
UPS/electrical room	1	20'x25'	500 SF	▪ Ground level ▪ Access from TC&C	▪ 3-ton AC unit ▪ 9' vertical clearance ▪ 3'x 7' access door	▪ Serves both TC&C and electrical requirements
Electrical closet	2	6'x 8'	48 SF	▪ One at each platform	▪ 3'x 7' access door	
Communication closet	2	6'x 8'	48 SF	▪ One at each platform	▪ 3'x 7' access door	
Janitor/storage	2	10'x 20'	200 SF	▪ Ground level ▪ At each station entrance	▪ 3'-6"x 7' access door ▪ V/AC	

Activity/Space	Quantity	Size	Area	Operational/ Locational Needs	Design Criteria	Notes
Trash room	2	6'x 8'	48 SF	▪ Ground level ▪ Exterior access ▪ At each station entrance	▪ 3'-6"x 7' access door ▪ Ventilated	
Security staff room	1	12'x 25'	300 SF	▪ Ground Level ▪ Separate exterior entrance	▪ 3'x 7' access door ▪ V/AC	▪ For Honolulu Police Department use
Station manager's booth	2	8'x 8'	64 SF	▪ Adjacent to fare gates ▪ At each station entrance	▪ Accessible from free and paid areas ▪ ADA accessible ▪ V/AC ▪ 3'x 7' access door	▪ Standard drawings to be provided
Restroom	2	8'x 8'	64 SF	▪ Near station manager's booth for observation and control ▪ At each station entrance ▪ Within fare paid area	▪ ADA accessible ▪ Unisex/single occupancy ▪ V/AC ▪ 3'x 7' access door	▪ Serves staff and general public
Ticket vending machines and queuing	TBD by RTD	4'x14' each	56 SF each	▪ Prior to fare gates in free area	▪ Number of machines varies with passenger volumes	▪ Standard drawings to be provided
Fare collection machines and queuing	TBD by RTD	3'x 36' each	108 SF each	▪ One line for each platform ▪ Ground level (concourse in special situations)	▪ Gate for ADA ▪ Number of gates varies with passenger volumes	▪ Standard drawings to be provided ▪ Space allocated but not installed
Advertising	As available	As available	As available	▪ Wall mounted ▪ Eye level	▪ Lighted (type TBD)	▪ Policy TBD by RTD
TheHandi-Van parking	1	10'x 20'	200 SF	▪ Adjacent to station entry ▪ Pullout from curb travel lane		
Maintenance vehicle parking	1	10'x 20'	200 SF	▪ Adjacent to TC&C Room	▪ Curb cut from street	
Bicycle racks	20	2'x 5' each	200 SF	▪ Adjacent to each station entry		
Entry plaza	2	30'x 50' min	1,500 SF	▪ At each station entry	▪ Landscaped	▪ To be accommodated as site allows

10.3.6 Platform

A. General

1. Stations shall have raised platforms at a level 3.77 feet above the top of rail (dimension subject to final determination). Center platform, side platform, and multiple platform station configurations shall be used in the design of the stations. RTD shall determine the specific platform types for each station.
2. The detectable platform edge detail design shall be consistent with ADAAG standards, and regulations and will be shown on the standard drawings as a systemwide standard detail.
3. Clear, unobstructed views of all areas of the platforms shall be provided by minimizing the number of canopy columns and equipment blocking those views.
4. In general, platform entry points shall be evenly distributed to reduce congestion and walking distances.
5. Platforms shall be sized to accommodate the patronage expected at the station.
6. Elevator, escalator, and stair-queuing space shall be free of any and all obstructions.
7. Station canopies shall be provided along a minimum of one-third of a platform's length and shall, at a minimum, cover all stairway, escalator, and elevator landing areas along those platforms.

B. Platform Widths

1. The minimum width of a center platform is 30 feet 0 inches.
2. The minimum width of a side platform is 12 feet 0 inches where the vertical circulation elements (stairways, escalators, and elevators) are located outside the limits of the platform.
3. In no case shall the clear distance between the edge of the platform and the obstruction be less than 8 feet 0 inches, unless stipulated by RTD.

C. Platform Lengths

The length of the boarding platforms shall be 240 feet.

10.3.7 Vehicle Clearances

Refer to Chapter 4, Track Alignment and Vehicle Clearances and Chapter 12, Passenger Vehicles.

10.3.8 Elements of Continuity and Element of Variability

Station design elements are divided into two classifications: Elements of Continuity and Elements of Variability. Elements of Continuity are standard designs established for the purpose of systemwide station identity, functional consistency, and a reduction in capital, operations, and maintenance costs. They include systemwide components such as signage, elevators, and escalators; systems equipment; ancillary facilities; and the guideway structure, as listed in Table 10-4.

To encourage station designs that are context-sensitive and historically and culturally expressive of specific locations, a certain level of design freedom will be permitted through the use of Elements of Variability.

10.3.9 Weather Protection

A. Canopies

Protection from the rain shall be provided for the following station areas:

1. Station Entrances: The free area of ground-level station entrances, within the limits established by the location of the station closure gates, shall be protected from rainfall.
    a. The free area associated with station entrance plazas, outside the station closure gates but within the limits of the property owned by the transit system, may be covered in part or in whole as determined by RTD on a case-by-case basis.
    b. The paid area of ground-level station entrances shall be protected from rainfall.
2. Station Concourses: All areas of station concourses shall be protected from rainfall, as shall all stairways and escalators connecting to and originating from each concourse.
3. Station Platforms: A minimum of one-third of each platform's length shall be protected from rainfall. To ensure coverage of all stairway, escalator, and elevator landings, this proportion may be increased.
4. Pedestrian Bridges: Pedestrian bridges connecting the system's facilities, cross-street bridges from station entrance to station entrance, station entrances to bus loading zones, etc. shall be provided with canopies to protect patrons from rainfall. Exceptions to these criteria shall be considered on a case-by-case basis.
5. Bus Bays: A minimum of 100 square feet of canopy coverage/bus shelter shall be provided for each transit center bus stall. Canopies providing coverage from station entrances to bus loading areas shall be considered on a case-by-case basis and determined for inclusion by RTD.

Table 10-4: Elements of Continuity/Variability

Element	C or V
Systemwide Elements	
Information devices, all signs/graphics, including accessibility signs/graphics	C
• Station markers	C
• System and station vicinity/maps	C
• Bus information	C
• Directional signing and graphics	C
• Identification	C
• Regulatory	C
• Variable message signs	C
Vertical circulation	
• Stairs	C
• Escalators	C
• Elevators	C
Communications and train control	
• Public address speakers	C
• Public address systems for hearing impaired	C
• Radiax cable	C
• Fire phones	C
• Emergency telephones	C
• Administrative telephones	C
• Patron assistance telephones	C
• Patron assistance for hearing impaired	C
• Maintenance telephones	C
Station control and security	
• Intrusion alarms	C
• CCTV equipment	C

Element	C or V
• Safety/security accessibility signing	C
Fare collection equipment	
• Ticket vending machines	C
• Fare Barriers	C
• Fare collection machines	C
• Emergency exit gates	C
• Accessible gates (for the disabled)	C
Materials, building components, and fixtures integral with station construction	
Site development plazas	V
• Paving	V
• Streets, curbs, and gutters	
• (City standards)	C
• Walkways	V
• Retaining walls	V
• Bollards, bumpers	V
• Handrails/railings	V
• Landscaping	V
• Fences	V
• Benches	V
• Bus stop shelters	C
• Trash receptacles	C
• Planters	V
• Lighting (lamp)	C
• Lighting (fixture)	V

Element	C or V
• Bicycle racks	C
• Bus bays	C
Station	
• Station manager's booth	C
• Platform configuration (per prototypes)	C
• Platform seating	C
• Trash receptacles	C
• Public address speaker housing	C
• Fare collection equipment	C
• Doors, gates, and hardware	C
• Floor material	V
• Wall and ceiling finishes public areas	V
• Hose bibs	C
• Lighting (lamp)	C
• Lighting (fixture)	V
• Security gates at station entrances	C
• Acoustical materials and details	V
• Escalator cladding, lighting, and detailing	C
• Elevator enclosure design and detailing	C
• Elevator cab design and detailing	C
• Concourse configuration	V
• Smoke and exhaust enclosure	V
• Railings/handrails—public areas	C
• Railings/handrails—emergency exits	C
• Linear platform edge detail and material	C
• Stairway details and materials	C
• Electrical outlets	C
• Platform service gates	C

Element	C or V
• Fire hose cabinet	C
• Emergency telephone	C
• Crowd control devices	C
• Ancillary rooms	
• Incoming power room	C
• Train control/communication room	C
• Substations	C
• Auxiliary electrical rooms	C
• Battery room	C
• Miscellaneous auxiliary rooms	C
• Toilet room—fixtures, accessories materials	C
• Drinking fountains	C
• Custodial rooms	C
• Trash room	C
• Staff room	C
• Fan rooms	C
• Storage rooms	C
• Utility boxes	C
• Doors and hardware	C
• Ejector room	C
• Sump room	
• Elevator Machine Room	C
• Mechanical grates, louvers, and grilles	
Artwork	V
Advertising	C

C = Elements of continuity
V = Elements of variability

B. Protection from Sunlight

The canopies described above shall provide a large measure of protection from the sun for transit passengers. Additionally, full coverage of the fare vending and fare collection machines shall be provided such that direct sunlight does not reach these machines since sunlight may affect their photo sensors and thus their performance and operation.

C. Windscreens

Windscreens shall be provided at station platforms to protect patrons from wind and wind-blown rain. Although windscreen design varies significantly between center and side platform stations, the following criteria is to be followed in their design and placement:

Windscreens shall be provided on the platform only for the full extent of the canopy.

10.3.10 Seating

A. Seating shall be provided at station entrances, along station platforms, and at bus waiting areas.

1. Station Entrances: Seating shall be provided at station entrances, both within the free area limits established by the location of a station's closure gates and to a larger extent within the station's entrance plazas.

2. Station Platforms: The design and placement of platform seating or leaning rails varies significantly between center and side platform stations. Center platform seating shall be configured as back-to-back assemblies, while side platform seating shall be designed integrally with the parapet wall.

   a. At center platform stations, seating is to be along the centerline of each platform, located such that it does not interfere with the movement of passengers, particularly in stairway, escalator, and elevator landings. Platform seating both within and beyond the limits of the platform canopies is encouraged.

   b. At side platform stations, seating is to be along the back of the platform. Similarly, it shall be located such that it does not interfere with passenger movement, particularly at the landings of vertical circulation elements, and is encouraged beyond the limits of the platform canopies.

3. Transit Center Bus Waiting Areas: Seating shall be provided both within each bus shelter and outside their limits, located such that it does not impede the flow of passengers boarding or alighting from buses.

4. Seating on station platforms shall be configured as shown on the architectural standard drawings.

10.3.11 Trash Receptacles

Standard trash receptacles shall be provided on the platforms, at ticket vending areas, and at bus bays. Trash receptacles shall be bolted down to avoid removal by unauthorized persons. Liners shall conform to a standard 15-gallon receptacle.

Maximum travel distance to the nearest receptacle on the platforms shall be 70 feet. A minimum of one receptacle per ticket vending area and three per platform shall be provided.

10.4 STATION ENTRANCES

Successful siting, layout, and design of station entrances probably contributes more than any other station functional area to attracting passengers to the system. Given the overall importance of station entrances, the following criteria and considerations shall be followed and addressed in their design:

A. Station entrance design shall embody Honolulu and Hawaii's rich cultural heritage in their physical form, as suggested in the *Design Language Pattern Book*.

B. Entrance designs configured in a similar manner and layout from station to station, using standard elements and functional sequences, will enable all passengers, including tourists, the elderly, and the physically handicapped, to find the system user-friendly and inviting.

C. Entrance designs shall be context-sensitive and functionally integrated with site-specific pedestrian and vehicular networks. Particular care shall be taken in the placement and orientation of station entrances to pedestrian crosswalks at intersecting roadways and mid-block crosswalks where they exist. Chapter 3, Environmental Considerations, sets forth specific guidelines and criteria governing the orientation and inter-relationships of the entrance design and placement of the adjoining vehicular modes that serve station entrances.

D. Critical to station entrance design is a clear understanding of the functional sequences traversed by passengers entering the station versus those exiting the station. A right-hand movement orientation, clear and logical movement scenarios through properly ordered functions, the provision of adequate queuing areas, and a separation of cross-flows are all imperative. Station entrance functions shall also accommodate short-term waiting by passengers exiting the station who may wish to wait within the station proper for friends, to be picked up, for example.

E. Prototype station design and the conceptual design work have identified two basic station entrance configurations: one where the station manager and the fare vending and fare collection machines are located at ground level and another where the footprint of a station entrance is minimized by placing the station manager and the fare vending/collection activities at the concourse level. The determination of which station entrance configuration to use at each station shall be made by RTD.

F. Station entrances shall be characterized by a feeling of openness and transparency similar to open-air pavilions. While secure during non-operating hours, this openness will contribute in large measure to their being user-friendly, inviting, safe, and easily monitored.

G. Key to the operation of each station entrance is the provision of a station manager. The manager's booth shall be located to enable clear visibility of the station entrance and entrance plaza, the fare vending and collection machines, the vertical circulation elements, the restrooms, and other key functions of the station entrance.

H. Security gates at each station entrance shall be electric roll-up grilles.

I. Station entrance designs shall incorporate information displays and handouts explaining the many aspects of the system, including route and neighborhood maps, fare structure explanations, and connecting bus route data. All such displays shall be carefully integrated into each entrance's arrival and departure passenger movement sequence.

10.5 VERTICAL CIRCULATION

10.5.1 Introduction

This section lists the main principles and standards relevant to the design of vertical circulation elements, including escalators, elevators, stairs, and pedestrian ramps.

A. All stations will require some form of vertical circulation, such as ramps, stairs, escalators, and elevators.

B. Escalators and stairs shall be sited so that they carry passengers to and from the platform(s) at a location convenient for boarding and alighting from their particular train. Changes of direction should be avoided when possible. The vertical circulation elements shall be strategically located at all station levels to enable circulation routes within each station to be as direct as possible.

C. Ultimate quantities of stairs and escalators shall be determined by RTD. In cases where stairways or escalators are deferred by RTD to a later date (after the opening of the station for revenue service) when increased passenger loading may necessitate their addition, the Station Designer shall provide for such future provisions in the station's preliminary engineering and final design drawings.

D. Elevators from street level to concourse level, and from concourse level to platform level, will be provided as required to make the system accessible to the disabled, as well as for maintenance equipment.

E. At-grade stations shall have, in order of preference, sloping walkways, ramps, and/or stairs. In addition to stairways, aerial stations will require other vertical circulation elements, such as elevators, escalators or both.

10.5.2 Basic Goals

A. Safety, achieved through the provision of adequate queuing spaces (see Table 10-2, proper relationship of basic vertical circulation elements, and the details of construction.

B. Maximum convenience for patrons, achieved through the establishment of uniform circulation patterns throughout the system's stations.

C. Comfort, achieved through proper sizing and layout of the vertical circulation elements.

D. Facilities designed to provide for the physically disabled.

E. Standard design to facilitate maintenance.

10.5.3 Layout Requirements

A. All stations must have at least one main entrance/exit to the street level.

B. Where changes in level occur, elevators, stairs, and escalators shall be provided at each station.

C. Additional stairs and escalators shall be provided between the platform and concourse and between the concourse and street to clear the platform of detraining passengers prior to the arrival of the next train.

D. To fulfill this requirement, sufficient vertical circulation shall be provided to allow the passage of the "Peak Five Minute Patronage" (pp5m) in five minutes or less. For this purpose, capacities of vertical circulation elements shall be assumed (Table 10-5).

Table 10-5. Assumed Capacities of Vertical Circulation Elements

Element	Capacity
Escalator	
48 inches nominal width @90 fpm	400pp5m
Elevator	
Each direction	65pp5m
Stair or ramp with slope of 4 percent or steeper (per 22-inch-wide lane)	
Up direction	144pp5m
Down direction	155pp5m
Horizontal corridor or ramp with slope flatter than 4 percent	150pp5m

Note: For ramps and horizontal corridors, a 1-foot, 0-inch buffer shall be provided at side walls; this width shall be discounted in determining effective lane width.

E. An unobstructed run-off or queue space shall be provided at each end of all stairs and escalators. This space shall have a minimum length of 20 feet at escalators and 15 feet at stairs. Where stairs and/or escalators oppose one another at the same level, the total unobstructed run-off/queue space may be reduced by 25 percent (see Table 10-2).

F. All vertical circulation elements shall comply with the requirements as referenced under the Codes and Standards Section.

G. Escalators and stairs, or ramps, shall be provided between station levels in accordance with the following criteria:

1. Elevation difference less than 18 inches—ramp only
2. Elevation difference at least 18 inches but not greater than 20 feet—stairs only
3. Elevation difference greater than 20 feet but not greater than 40 feet:
    a. Where reverse flow is 65pp5m or less—one escalator and one stair
    b. Where reverse flow exceeds 65pp5m—two escalators, one up and one down, and one stair

4. Elevation difference greater than 40 feet—two escalators, one up and one down, and one stair

H. Guardrails for ramps shall be continuous 34 to 38 inches in height, unless next to an elevation drop-off of 18 inches or more, where a minimum of a 42-inch-high guardrail is required.

10.5.4 Stairs

A. General Requirements

1. Noncombustible materials shall be used for stair construction.
2. All treads, landings, and nosings shall have slip-resistant surfaces.

B. Standard Stair Widths (Minimum)

1. For public use: 5 feet 6 inches.
2. Emergency stairs: 4 feet 3 inches minimum clear.
3. Emergency stairs adjacent to area of rescue: 4 feet 7 inches minimum (48 inches between handrails).

C. Stair Landings

1. For straight run stair, minimum and recommended length of landing: 4 feet 0 inches.
2. For return stair, minimum width of landing must be at least equal to width of stair.
3. Concealed reverse landings will be avoided in public stairs.

D. Treads and Risers

1. Public stairs running parallel to and adjoining escalators shall have a tread and riser relationship with a component of 30 degrees.
2. The maximum height of riser at public stairs shall be 7 inches. Minimum tread shall be 12 inches.
3. Maximum vertical distance between landings in any one run of public stairs shall not exceed 12 feet.
4. Solid treads and risers shall be used.
5. Tread and riser dimensions shall be uniform in any one stair.
6. Minimum allowable number of risers is three. Where a change in elevation is less than 18 inches, a ramp shall be used.
7. Minimum headroom at public stairs measured vertically from the line of nosing: 10 feet 0 inches. Continuous soffits, without obstructions, should be held to 10 feet 0 inches.

8. Emergency stairs shall have a maximum 7-inch riser and a minimum 12-inch tread. The number of risers in any one run of stairs shall not exceed 20. The minimum clear headroom shall be not less than 8 feet 0 inches measured perpendicular to the tread at nosing.

9. Tread riser formula: The ratio of risers to treads shall fall within the following limits: 2R + T = 25 inches to 27 inches.

E. Handrails

1. Height of railing: 2 feet 10 inches measured vertically from the top of the tread, at the nosing, to the top of the handrail (2 feet 10 inches at landings and 3 feet 8 inches around well openings or concourse edge).

2. Handrails may extend a maximum of 3-1/2 inches into required stair width.

3. Handrails shall be continuous through landings for the full length of the stair.

4. Handrails should extend a minimum of 12 inches beyond the top riser and 12 inches plus one tread width beyond the bottom riser.

5. Handrails must be provided on both sides of all stairs.

6. Maximum allowable stair width without a center handrail: 7 feet 4 inches. Center handrails could be provided on narrower stairs where needed or required to aid circulation. All stairs (except monumental stairs) in excess of 7 feet 4 inches wide must have center handrails spaced no more than 7 feet 4 inches apart.

7. Where a balustrade is not solid, the clear distance between vertical balusters must not exceed 4 inches.

8. Handrail ends shall be returned to the wall or curved down 90 degrees where free-standing.

9. For public stairs, avoid horizontal design of intermediate rails to avoid ladder-type effect and to discourage children from climbing the rail.

10.5.5 Escalators

A. General

Escalators should be provided where there is a rise greater than 20 feet vertically.

B. General Requirements

1. Direction: Dual direction.

2. Width: All escalators shall be 48 inches nominal width.

3. Speed and Capacity: The speed of escalators shall be 90 and 120 feet per minute (fpm) in both the up and down directions. They shall be capable of operating 24 hours non-stop.

4. Rise and Slope: Rise (H) is the true vertical distance between working points (WP). All escalators shall be installed with the line of step nosings 30 degrees from true horizontal.

C. Structural Consideration

A slip connection at the head of escalators in aboveground stations will be provided by the escalator manufacturer to allow for movement (deflection, torsion, etc.) due to the dynamic loading on the station structure caused by the train as it moves in and out of the station. Escalator trusswork and other structural members are not to receive loads other than those imposed by the escalator itself (see architectural directive drawings for further information).

D. Floor Slope

Landing plates must be level. Adjacent floors shall be sloped away from the escalator. The texture of the floor in proximity to the landings shall contrast with the finish of the surrounding area for detection by the visually impaired.

1. Safety Requirements for Escalators Treads

   a. At the top and bottom of each escalator run, at least three contiguous treads shall be level beyond the comb plate before the risers begin to form.

   b. All escalator treads shall be marked by a strip of clearly contrasting color, 2 inches in width, placed parallel to and on the nose of each step. The strip shall be of a material that is at least as slip resistant as the remainder of the tread. The edge of the tread shall be apparent from both ascending and descending directions.

   c. Noise produced by escalators operating individually in either direction under no load and under maximum load in the station environment shall not exceed 55 dBA 5 feet above the tread at the entrance combs at both ends of the escalator.

   d. Skirt guards shall be provided

2. General Requirements

   a. Stop controls onsite and at the Central Control Facility shall be provided.

   b. Emergency-stop buttons accessible to the public shall be provided at the top and bottom of each escalator behind a transparent cover. When activated, the emergency stop button shall cause a local alarm to be activated in the station manager’s booth and at the Central Control Facility.

   c. Publically inaccessible remote stopping capability shall be provided from the station’s Emergency Management Panel. Each escalator shall be equipped with glide stop capability for use during remote stopping.

   d. Weather protection for outdoor escalators shall be provided.

10.5.6 Elevator

A. Planning Requirements

1. Elevators (or ramps when less than a full story level change) shall be installed in all stations where there are differences in level. Depending on the configuration of the station, a minimum number of elevators shall be used to serve the separated areas and levels.

2. Elevators shall be located to minimize travel distances for the elderly and disabled.

3. Elevators contained within station entrances shall be placed as close to the entranceway as possible to decrease travel distances for the elderly and handicapped to the TheHandi-Van, bus loading areas, and parking areas. A convenient elevator location is also desirable for Emergency Medical Service staff that may use the elevator to transport infirm or injured passengers from stations to their vehicles.

4. Elevator cabs shall have transparent panels to allow an unobstructed view both into and out of the cab.

5. Elevator cab finish materials shall be determined by RTD or its designee during the preliminary engineering design process. Transparent surfaces shall be laminated glass.

6. Elevator Hoistway

    a. Ground level to concourse, ground level to platform, and concourse to platform elevator enclosures shall be configured as set forth in the architectural standard drawings.

    b. Hoistway and elevator entrance shall comply with ADAAG and Honolulu Municipal Code.

    c. Safety glazed in a metal framed system.

7. Elevator Cabs

    a. Safety glazed in a metal framed system with safety glazed doors. Front panels alongside doors shall have opaque walls.

    b. Visibility into cab at all points of travel to enhance security. Elevators in stations are to be located so as to make the requirement for visibility of cab effective on all four sides when possible, but no fewer than two sides.

    c. An accessible intercom device shall be connected to the station manager’s booth and the security center at the Operation Control Center (see Chapter 15, Communications and Control).

    d. Speed from 125 to 150 fpm.

10.5.7 Pedestrian Ramps

A. Slope of Ramp: 1 foot, 0 inches in 20 feet 0 inches (5 percent) preferred; not to exceed 1 foot, 0 inches in 12 feet 6 inches (8 percent) maximum.

B. For ramps with a slope greater than 5 percent, landings are required for each 2-foot 6-inch rise in elevation.

C. Surface of ramps shall be slip-resistant. Static coefficient of friction shall be 0.8 as defined by ASTM C1028.

D. Cleaning trough is not required for ramps.

10.6 ACCESSIBILITY FOR INDIVIDUALS WITH DISABILITIES

10.6.1 Introduction

The following design requirements shall render the Project accessible and usable by the elderly and individuals with disabilities. The system shall contain specific design provisions to reduce and eliminate architectural or transportation barriers to the use of the system by the disabled, and to accommodate all persons who, without intervention or assistance by others, can arrive at and enter the system.

10.6.2 Systemwide Criteria

A. Signage and Graphics

Signage shall conform to the standards specified in the Standards for Accessible Design. The International Symbol of Accessibility shall be displayed according to these standards to identify accessible facilities and elements.

Raised and Braille characters shall be provided at signs identifying station names, signs bearing instructions, and all information for use of emergency phones, automatic fare vending, collection, and adjustment equipment, and where required by ADAAG. For elevator graphics, see ADAAG.

B. Emergency Warning Systems

Emergency warning systems shall include both audible and visible alarms, in accordance with ADAAG.

C. Controls

All equipment required to be accessible shall be positioned and mounted in such a way that wheelchair occupants can use the controls. Anthropometric standards are addressed in ADAAG. This requirement applies to, but is not limited to, the following equipment: emergency and system information telephones; fare vending, collection, and adjustment equipment at stations/stops; and furnishings such as drinking fountains.

Installation height of manual fire alarm initiating devices shall be as specified in ADAAG.

In facilities where system employees have access (e.g., non-public portions of stations, the yards and shops, and the Central Control Facility), accessibility of controls and operating mechanism shall be as defined in ADAAG.

D. Hazards

Hazards due to abrupt changes in floor level, ground and floor surfaces, and gratings shall be mitigated in accordance with ABA/ADAAG.

Objects protruding from walls or ceilings shall be located so as to provide the dimensional clearances cited in ADAAG.

E. E. Doors

Doors in stations required to be accessible to the public or system employees shall be as specified in ADAAG.

10.6.3 Stations

A. Access

All entrances to buildings and facilities shall be made accessible to individuals with disabilities.

Site development and grading shall be designed to provide access to entrances and normal paths of travel. Where necessary, pedestrian ramps, curb ramps, and/or elevators shall be incorporated in such paths.

Specific requirements for elements of vertical circulation (ramps, stairs, and elevators) are discussed in the Vertical Circulation section of these criteria.

Floors and levels within a station/stop shall conform to USDOT regulations (49 CFR 37, Appendix A). At multilevel stations, direct access shall be provided for individuals with disabilities between levels. Walks and sidewalks at the station site shall be fully accessible.

B. Platform

The platform edge strip (detectable warning pavers) shall conform to ADAAG and USDOT standards and shall run the full length of the platform and contrast visually with adjoining surfaces.

Where seating is provided, there shall be spaces provided for wheelchair users and the seating shall be accessible.

C. Communications

Emergency communications equipment and passenger assistance phones shall be accessible.

A means of conveying equivalent information announced through the public address system shall be provided for persons with hearing loss or who are deaf.

10.6.4 Vertical Circulation

Ramps, stairs, and elevators shall be used to provide access to all station/stop facilities and between levels of multistory stations/stops. They shall also be provided in the operations and maintenance buildings and other facilities to which only system employees have access as necessary, given the job requirements. Any facility open to the public shall be accessible.

A. Ramps

A path of travel with a slope greater than 1:20 (5 percent) shall be considered a ramp. Ramps shall not be provided at stations where the vertical rise is greater than 16 feet.

1. Pedestrian ramps shall have a minimum of 48 inches in clear width, except that pedestrian ramps serving primary entrances to buildings having an occupant load of 300 or more shall have a minimum clear width of 60 inches.
2. The maximum slope shall be a 1-foot rise in 12 feet of horizontal run with a cross slope no greater than 1:50, although more gradual slopes are desirable.
3. Ramp landings shall be provided at the top and bottom of each ramp at intervals not exceeding 30 inches of vertical rise, and at each change of direction.
4. Handrails shall be provided on each side of any ramp whose slope exceeds 1:20 or whose rise is greater than 6 inches. The handrails shall be continuous, placed 34 to 38 inches above the ramp surface, and shall extend at least 12 inches beyond the top and bottom of the ramp, with returned ends.
5. The surface of ramps shall be slip-resistant, and wheel guides or curbs shall be provided on ramps longer than 10 feet.

B. Stairs

1. The upper approach and the lower tread of each stair shall be marked by a strip of clearly contrasting color at least 2 inches wide, placed parallel to and not more than 1 inch from the nose of the step or landing to alert the visually impaired. The strip shall be of material that is at least as slip-resistant as the other treads of the stair.
2. Where stairways are located outside a station, the upper approach and all treads shall be marked by the strips described above.
3. Open risers are not permitted. Treads shall not have abrupt edges at the nosing, and shall not project more than 1-1/2 inch past the face of the riser.

C. Elevators

Elevators shall be provided at aboveground stations and in all accessible buildings having more than one floor level. They shall conform to the requirements in ADAAG and ANSI A117.1.

1. The minimum inside clear dimensions of the car shall be 96 inches by 72 inches, to accommodate a gurney. The clear opening width of the hoistway and elevator entrance door opening shall be 42 inches.

2. The elevator shall have an automatic leveling feature with a tolerance of ± ½ inch (with respect to the adjacent floor landing), which shall be maintained under normal loading and zero loading conditions.

3. Passenger elevators shall be provided with at least one handrail at a nominal height of 34 to 38 inches above the car platform, preferably on the rear wall.

4. Elevator floor buttons shall be no higher than 54 inches from the car floor for side approach and 48 inches for front approach.

5. Emergency controls shall be grouped at the bottom of the elevator control panel and shall be no lower than 35 inches to the center line from the car floor. The emergency telephone handset shall be positioned no higher than 48 inches above the floor and shall be of hands-free operation.

6. Hall call buttons shall be within 42 inches of the floor. Other factors that shall comply with ADAAG are minimum button dimensions, tactile, Braille, and other identification for the visually impaired, visual and audible car call signals, non-voice emergency communication, hall lantern location and dimensions, and floor designations at each hoistway entrance.

10.6.5 Fare Collection

A. The baseline fare collection concept for the system is self-service. Initially it will be an honor system with provisions for future fare barriers. The location of the fare gates provides the physical separation between a free area and a paid area of a station. Ticket vending machines will be provided at each station.

B. The control and operating mechanism of all ticket vending machines shall be no higher than 48 inches above the finished floor if the clear floor space is such that it allows forward approach only, or up to 54 inches above the finished floor if the clear floor space allows parallel approach by a person in a wheelchair. Clear floor space and maneuvering clearance requirements shall comply with ADAAG standards

C. At stations providing direct physical interchange with other transit modes, means shall be provided for wheelchair occupants to make the transfer independently (i.e., with no more assistance required from the operating staff than is required by other passengers).

D. Both the customer and employee side of the station manager's booth shall be made accessible to individuals with disabilities.

10.6.6 Emergency Egress Provisions

The design of the rail system's facilities shall include provisions to enable the safe, timely, and unsupervised evacuation of passengers and employees from all fixed structures and facilities.

Vehicle evacuation is to be accomplished only under the direct supervision of trained emergency forces or system employees. In particular, the design shall include provisions and procedures for supervising the safe, timely, and orderly evacuation of passengers with disabilities from vehicles located anywhere in the system.

10.6.7 Operations and Maintenance Facilities

The operations and maintenance facilities include the operation control center, the maintenance and storage facility, and portions of stations/stops open to system employees but not to the public.

Employee work areas shall be designed to be fully accessible.

10.7 SUSTAINABLE DESIGN

10.7.1 Introduction

The design of an urban transit system as sustainable infrastructure requires the use of creativity and technical understanding to achieve cost-effective solutions that are not dependant on traditional patterns of resource consumption. A sustainable design approach to the Project's stations and fixed facilities will help ensure that sustainability principles and practices are integrated into the Project's design and construction. The design of the system will be consistent with the City's "Principles of the 21st Century Ahupua'a" Vision, and the City's Sustainability Plan.

10.7.2 Basic Goals

A. Integrate sustainability principles and practices, including multimodal access into the planning, design, and construction of stations and related facilities.

B. Apply sustainable techniques and procedures into the Project's maintenance procedures and operations in a cost-effective manner.

C. Incorporate proven sustainable materials, methods, and technologies into station design to increase life-cycle value and reduce energy and resource use.

10.7.3 Site Design Goals

A. Promote sustainable, transit-oriented development in the communities the Project serves to maximize the use of the system as the primary mode of transportation.

B. Enhance the use of resource-efficient and environmentally friendly access modes (e.g., bikes or walking), and other sustainable features at stations.

C. Avoid development of inappropriate sites and reduce site disturbance and environmental impacts from the location of a building or station structure on a site.

D. Limit disruption to the hydrology of natural waters by reducing impervious cover and increasing on-site infiltration. Incorporate on-site rainwater retention methods such as bio-retention cells and natural swales.

E. Limit disruption and pollution of natural water flows through innovative stormwater management design.

F. Reduce heat islands and incorporate water efficient and native landscape materials.

10.7.4 Station Design Goals

The design of stations will be based on sustainable methods of construction and the selection of materials, design approaches, and construction methods and materials. Use of innovative green technologies and Green Specifications as identified in the U.S. Green Building LEED® rating system is encouraged.

A. Reduce the heat island effect (thermal gradient differences between developed and undeveloped areas) to minimize impact on microclimate and human and wildlife habitat.

B. Use roofing materials having a Solar Reflectance Index equal to or greater than 50 for a minimum of 75 percent of the roof surface.

C. Reduce Light Pollution.

1. Minimize light trespass from the building and site; reduce sky-glow to increase night sky access; improve nighttime visibility through glare reduction; and reduce development impact on nocturnal environments.
2. Only light areas as required for safety and comfort. All non-emergency interior lighting shall be automatically controlled to turn off during non-business hours. Provide manual override capability for after-hours use.

D. Increase use of building products that incorporate recycled content materials, thereby reducing impacts resulting from extraction and processing of virgin materials.

E. Commit to the use of local and regional materials, recycled construction materials, and those with recycled content.

F. Reduce energy consumption and consider the generation of a portion of each station's and support facility's energy requirements through incorporation of new generation integrated photovoltaic technology in canopy structures and roofs.

G. Reduce potable water use as well as the generation of wastewater.

H. Reduce material usage, minimizing superfluous materials and finishes while providing incentives for "zero-waste" construction activities.

I. Consider rainwater retention for non-potable water usage (e.g., toilet flushing and irrigation).

J. Stations and support facility designs should be configured to take maximum advantage of day-lighting and natural ventilation.

K. Reduce the use of volatile organic compounds in all adhesives, sealants, paints, coatings, and interior finishes.

10.7.5 Maintenance and Storage Facility

The Maintenance and Storage Facility will incorporate proven sustainable materials, methods, and technologies into their facility design to increase life-cycle value, including a reduction in energy and resource use, and to enhance the health and comfort of system employees and customers.

The main shop shall be designed to achieve a LEED Silver certification level as defined by the U.S. Green Building Council LEED rating system for new construction.

10.7.6 Life Cycle and Maintenance Components

Components will be selected so as to effectively incorporate proven sustainable materials, methods, and technologies into the Project's Facilities Standard to increase life-cycle value, including a reduction of energy and resource use and to enhance the health and comfort of employees and patrons.

10.8 MATERIALS AND FINISHES

10.8.1 Introduction

The purpose of this section is to specify basic requirements and criteria established for the finish materials to be used in public areas of the stations. While harmony and attractiveness shall be considered in the selection and application of these finishes, RTD or its designee and the Station Designer shall ensure that the goals of safety, durability, ease of maintenance, resistance to vandalism, and aesthetic quality are achieved.

10.8.2 Basic Goals

A. Safety

1. Fire Resistance and Smoke Generation

   Reduce hazard from fire by using materials with minimum burning rates, smoke generation, and toxicity characteristics for station finishes, consistent with requirements of the Fire/Life Safety Criteria.

2. Attachment

   Material shall be secured to eliminate hazard from dislodgement due to temperature change, vibration, wind, seismic forces, aging, or other causes by using proper attachments and adequate bond strength.

3. Slip-resistant walking surfaces

   Increase pedestrian safety, in compliance with accessibility requirements, by using floor materials with slip-resistant qualities. Entrances, stairways, platform edge strips, and areas around equipment should have high slip-resistant properties.

   The static coefficients of friction in Table 10-6, as defined in ASTM C1028, shall be provided as a minimum.

Table 10-6: Coefficient of Friction

Public Horizontal Surfaces	Coefficient of Friction
Pubic horizontal surfaces within the paid areas of stations; entrances, concourses, platforms, and stairways	0.6 min

Public horizontal surfaces within the free area of stations as limited by the entrance enclosures and security closure gates	0.6 min
Non-public horizontal surfaces, exterior Exterior ancillary areas	0.6 min.
Non-public horizontal surfaces, interior Interior ancillary rooms	0.5
Detectable warning strip	Textured and visually contrasting, conforming to ADAAG Section 4.29.2
Stairs, ramps	0.8

B. Durability

Finish materials used within the stations shall be characterized by durable qualities such as wearability, inherent strength, excellent weathering qualities, and colorfastness. Finish materials shall have a useful lifetime of 50 years before their replacement is required.

C. Ease of Maintenance

1. Cleaning

   Reduce cleaning costs by using materials that do not soil or stain easily, which have surfaces that are easy to clean in a single operation, and on which minor soiling is not apparent. Materials shall be cleanable with standard equipment and non-toxic cleaning agents.

2. Repair or Replacement

   Reduce maintenance costs by using materials that, if damaged, are easily repaired or replaced without undue interference with the operation of the system. Spare materials shall be provided for tile and other unit materials in a quantity of approximately 2 percent of the total used.

D. Resistance to Vandalism

Select materials and details that do not encourage vandalism and that are difficult to deface, damage, or remove.

1. All surfaces exposed to the public are to be finished in such a manner that the results of casual vandalism can be readily removed with normal maintenance.

2. Station Designers are required to describe procedures for removal of more serious defacement for each proposed finish in public areas and within 9 feet of the floor surface.

E. Aesthetic Qualities

Choose materials that will create a feeling of attractiveness and quality that will instill civic pride in the station facilities. Materials shall be consistent with the cultural and historical guidance and recommendations set forth in the *Design Language Pattern Book*.

10.8.3 General Criteria

The following general criteria for finish materials are indicated to achieve the goals outlined above.

A. Surface Materials

Applied materials shall be hard, dense, non-porous, non-staining, acid and alkali resistant, for long life and low maintenance. Wall surfaces within reach of the public, up to 9 feet above the floor level may be finished with applied materials when it is determined that infill materials are needed and/or that the structural materials are not sufficient to withstand the projected wear.

B. Color

Lighter colors shall aid in the maintenance of higher illumination levels, with sufficient contrasts and accents to provide visual interest and conceal minor soiling.

C. Texture

Smooth surfaces are preferred over rough ones for ease in cleaning and because they are less prone to catch settling dust. Rough surfaces are desirable where a slip-resistant feature is important and are acceptable where surfaces are difficult to reach and are therefore unlikely to be cleaned very frequently. A rough surface may hold dust without being visually apparent.

D. Unit Size

Units should be large enough to reduce the number of joints yet small enough to conceal minor soiling and scratches and to facilitate replacement if damaged. Monolithic materials may be used if they have inherent soil-hiding characteristics that can be easily repaired without the repair being noticeable.

E. Joints

Joints are a major source of maintenance problems. Joints should be small, flush, limited in number, and of the best material. Horizontal joints should not be raked but should be flush or tooled concave. Monolithic materials should have adequate control joints and expansion joints at the proper spacing to prevent surface cracking. Floor finish joint widths shall be 3/8-of-an-inch wide maximum.

F. Cost

Materials shall be selected for long life, low maintenance, replacement considerations, and overall aesthetic and functional qualities. Their costs shall be subject to cost-benefit analyses that consider maintenance and replacement costs for such long-life facilities.

G. Availability

Materials should be selected that are readily available. Productions from the Hawaiian Islands use shall be strongly emphasized, followed by Mainland products and finally products that are not produced in the U.S.

H. Nonproprietary Materials

To obtain competitive bids and to comply with Federal regulations, proprietary items should only be used where it is established that no other material would meet the particular design requirements.

I. Installation Standards

Materials shall be detailed and specified to be installed in accordance with industry standards and manufacturer's printed directions.

J. Flammability

Finishes shall meet requirements of the Uniform Building Code NFPA 130 and NFPA 101.

1. Finishes for all protected exitways shall be Class I, as defined by the Uniform Building Code, and Class A as defined by NFPA 101.
2. Finishes in all other areas shall be Class II, as defined by the Uniform Building Code, and Class B as defined by NFPA 101.
3. Combustible adhesives and sealants may be used when they meet the requirements stated above.

K. Paint

Field application of all types of paint shall be kept to an absolute minimum. Materials with painted surfaces proposed for installation at stations shall be those with high durability, long-life paint systems that are factory applied and, most desirably, are baked onto the material/equipment at high temperatures.

10.8.4 List of Finished Materials

This list will apply to all facilities. For the use of items listed as "Acceptable," installation is subject to location and environmental considerations.

A. Floor Finish Materials: Finish to Provide Slip-Resistant Surface

1. Acceptable
   a. Monolithic Materials
      i. Concrete with appropriate finish to provide slip-resistant surface
      ii. Rusticated Terrazzo
   b. Unit Materials (minimum 4 inches by 8 inches by ¾ inch)

i. Natural granite: Mandatory at public stairs and platform edges; pre-warning strip to contrast with platform edge band

ii. Manufactured granite

iii. Terrazzo: Precast only, up to 24 inches x 24 inches, slip-resistant texture, with sealed surface

iv. Paver brick: Dense, hard

v. Quarry tile

2. Not Acceptable

a. Monolithic Materials

i. Bituminous toppings

ii. Synthetic resin toppings

iii. Resinous Terrazzo tile

b. Unit Materials

i. Resilient tile and sheet products in public areas

ii. Marble

iii. Mosaic tile

iv. Glazed ceramic tile

v. Wood

B. Wall Finish Materials

1. Acceptable

a. Monolithic Materials

i. Concrete—use of clear sealers may be considered in areas accessible to the public

b. Unit Materials: Minimum 2 inches by 2 inches

i. Glazed and unglazed ceramic mosaic tile

ii. Glazed and unglazed brick

iii. Precast concrete

iv. Structural glaze-faced concrete masonry units

v. Porcelain enamel steel panel—noncombustible assembly

vi. Laminated glass panels

vii. Concrete masonry units

c. Surface Applied Finishes

i. Clear sealer—on concrete surfaces or concrete masonry units

2. Acceptable for use for walls more than 9 feet above finished floor level

a. Smooth concrete

b. Acoustical panels

3. Base Materials

a. Ceramic Tile—Cove

b. Quarry Tile—Cove

c. Granite—Cove

4. Not Acceptable

a. Monolithic Materials

i. Rough or textured concrete (within 9 feet of floor immediately adjacent to public circulation and flow areas)

ii. Plaster

iii. Exposed steel as a wall finish

iv. Non-laminated glass

b. Unit Materials

i. Gypsum board (acceptable for two-hour rated enclosure at smoke exhaust duct where passing through ancillary space)

ii. Plastics

iii. Non-laminated glass

c. Surface-Applied Finishes

i. Vinyl wall covering

ii. Paint

iii. Special epoxy coatings

C. Ceiling Finish Materials

1. Acceptable

   a. Monolithic Materials

      i. Smooth concrete

   b. Unit Materials

      i. Non-corrosive metal panels with shop-applied coating, with perforations, with wrapped and encapsulated acoustical material

      ii. Rigid, cellular glass blocks

      iii. Structural wood

2. Not Acceptable

   a. Surface-Applied Materials

      i. Gypsum plaster

   b. Unit Materials

      i. Acoustic tile (ceramic and mineral, glass and wood fiber)

      ii. Gypsum board

      iii. Suspended plaster systems

D. Door Materials

1. Acceptable

   a. Flush hollow metal doors and frames

      i. Public areas—alkyd enamel finish

   b. Wire glass at doors with vision panels

   c. Laminated safety glass at elevator, glazed doors, and hoistways

2. Not Acceptable

   a. Anodized aluminum doors and frames

   b. Fluoropolymer finished doors and frames

   c. All upward-acting sectional doors

   d. All non-tempered, non-safety glass

E. Canopy Materials

1. Acceptable
    a. Steel with factory-finished aliphatic polyurethane coating
    b. Laminated glass
    c. Structural wood
    d. Coated fabric
2. Not Acceptable
    a. Non-laminated glass
    b. Uncoated fabric
    c. Plastics

F. Handrails

1. Acceptable
    a. Stainless steel
    b. Bronze
    c. Aluminum
    d. Factory-finished steel
2. Not Acceptable
    a. Uncoated steel
    b. Uncoated galvanized steel
    c. Polyurethane-coated aluminum or steel

G. Benches

1. Acceptable
    a. Concrete
    b. Granite
    c. Polyester powder-coated woven or punched steel
    d. Wood
2. Not Acceptable

a. Uncoated steel

b. Aluminum

c. Uncoated galvanized steel

10.9 ADVERTISING

10.9.1 Introduction

Advertising may be permitted in the stations subject to future determination. If permitted, it shall be subject to all local regulations, in particular those that state that such advertising cannot be seen from outside each station, from at-grade, or from elevated vantage points.

10.9.2 Basic Goals

Incorporate advertising, but only to the extent that the advertising does not interfere with the stations design elements, patron convenience, and safety and security, or adversely affect combustible loading.

Ensure that advertising, by its placement and treatment, does not interfere with orderly patron circulation. Placement of advertising on or adjacent to escalators, stairs, or system graphics will not be permitted.

Discourage defacement or damage by placement and form of advertising. Because of potential vandalism, merchandise display cases will not be permitted.

10.9.3 Criteria

Station Designers will identify potential spaces for advertising and submit to RTD for its review.

Advertisements will be carefully located, adjacent to areas of heavy traffic, but out of the direct passenger flow, so that they do not obstruct or retard such flow.

Capital, maintenance, and operating costs shall be the sponsor's/vendor's responsibility.

For related information, refer to the *Signage and Way-finding Manual*.

10.10 ARTWORK

10.10.1 Introduction

The purpose of this section is to identify the goals and general requirements of the City's Public Art Program as it pertains to the Project. The implementation of the station art program shall be in full compliance with the City's Public Art Program Ordinance that is administered by the Mayor's Office of Culture and the Arts.

This section of the criteria explains the intention of the RTD and Station Designers to involve the artists as members of the design teams and to integrate works of art into the design documents during the design phase.

10.10.2 Basic Goals

A. Enhance the everyday commuting experience and expand the public awareness of art through the commissioning of high quality art for the stations.

B. Enrich the rail transit system for both residents and visitors by creating a unique visual element or treatment for each station through relevant works of art that contribute to a sense of community identity and pride.

C. Heighten public awareness of the unique cultural and historical influences of the communities surrounding the stations.

D. Assist Honolulu in the preservation of the artistic and cultural heritages of all its people.

E. Encourage and provide equal opportunity for the development of cultural and artistic talents of the people of Honolulu.

10.10.3 General Requirements

A. Artwork will be incorporated into the station facilities and/or facility sites in accordance with the City's Public Art Program Ordinance. The Station Designers will be responsible for incorporating the artwork proposals into the preliminary engineering and final design drawings.

B. All artwork locations and materials shall be reviewed by the Station Designer and approved for code compliance, safety considerations, and acceptability vis-à-vis their impact on each station's functional requirements.

C. The Station Designer should review art materials for durability, maintainability, longevity, and fire-resistance, as well as for practical considerations with regard to fabrication and installation.

10.11 ACOUSTICS

10.11.1 Introduction

The purpose of establishing noise criteria is to determine the appropriate areas, absorption coefficients, and placements of the acoustical material to obtain the most economical and appropriate design for the station acoustical treatment that will result in a desirable acoustical environment at and around stations throughout the system.

10.11.2 Basic Goals

The basic goals of acoustical design are to achieve both physical and psychological comfort at stations through the following:

A. Control and reduction of noise from train operations and to provide control of train and equipment noise to mitigate impacts on nearby properties.

B. Provision for good intelligibility of announcements from the public address system.

C. Control of general crowd noise generated by patrons talking and walking or noise from exterior sources.

D. Assistance in the control of noise from the station's air conditioning system and other mechanical equipment contained within the station's ancillary spaces.

The acoustic treatment accomplishes these objectives by the absorption of sound energy as it impinges on the interior surfaces of the station, thus preventing multiple reflections and the build-up of reflected or reverberant sound energy. The amount of control of reverberation and the consequent reduction of noise obtained are dependent upon the area of the acoustical treatment, the absorption coefficient, and the placement of the treatment.

10.11.3 General Criteria

A. No long-distance echoes should be audible in public spaces when they are nearly empty.

B. Consideration must be given to the effect of project-generated noise on the area surrounding the line and station, and of street and highway noise coming into the station.

C. Acoustical insulation material shall be selected from noncombustible building construction materials, as defined by NFPA 101, Chapter 3, which fall in one of the following groups:

1. Materials no part of which will ignite and burn when subjected to fire.
2. Materials having a structural base of noncombustible material as defined above with a surfacing not more than 1/8-inch thick and has a flame spread rating not higher than 50 when tested per NFPA 251, Standard Methods of Fire Tests of Building Construction and Materials.

10.11.4 Special Criteria

A. General

1. Areas involved
    a. Entrance areas
    b. Concourses
    c. Platforms
    d. Stairways
    e. Escalators
    f. Elevators
2. Considerations

Where feasible and practical, these areas should be shielded from street and highway vehicle noise.

B. Ancillary Spaces

1. Areas involved: Ventilation and Air Conditioning Equipment Area

2. Considerations

a. Spaces for fans and other potentially noisy equipment shall be separated from public areas where possible. If direct access into such rooms from public areas cannot be avoided, provide doors with a suitable sound rating.

b. The criteria in Table 10-7 apply to noise from transit system ancillary facilities.

Table 10-7: Noise from Transit System Ancillary Facilities

Community Area Category	Transient (in dBA)	Continuous (in dBA)
Quiet residential	45	40
Average urban residential	50	45
Semi-residential/commercial	55	50
Commercial	60	55
Industrial highway corridor	65	60

10.12 LIGHTING

10.12.1 Introduction

The quality of the lighting design will greatly influence the appearance and attractiveness of the stations and will play an important role in enabling the public's acceptance of the system and the stations. Although the stations will vary in appearance, there should be an overall design unity throughout the system.

10.12.2 Basic Goals

A. Designs that maximize the use of daylighting in public spaces are encouraged. The use of artificial lighting, in daylight hours, should be limited to locations that require specific illumination levels for safety and security purposes.

B. Well planned lighting can assist in wayfinding and minimize confusion in station circulation and enhance the identity of the individual station.

C. Lighting should produce visual appeal. Variations in placement and selection of light sources as well as in application techniques, color, direction, and quality should be used to create interest and variety. However, extreme contrasts that create "dramatic" effects should be avoided (e.g., pools of light in a generally dark surround or alternating bands of very high and very low illumination).

D. Lighting of the station, platform areas, and parking lots shall be designed to deter crime and comply with the principles of CPTED.

E. Lighting design shall focus on energy conservation and the use of maximum energy-efficient products.

F. The use of standard lamps shall be encouraged, although a range of fixture types will be permitted. Establishing a limited range of lamp types will enable reasonable maintenance expenditures for replacement inventories and relamping activities.

10.12.3 Technical Requirements

A. Illumination levels

See Chapter 20, Facilities Electrical, for illumination levels.

B. Fixture placement

The coordination of fixture placement with respect to graphics, CCTV, telephones, speakers, and other miscellaneous elements should be given particular attention to minimize visual clutter.

C. Emphasis

It is desirable to use light as an indicator of areas of special importance, such as a fare vending area or station entrance. The highlighting of such areas is best accomplished by lighting emphasis on vertical surfaces (wall washing) rather than by pools of light on the floor. A bright surface perpendicular to the line of sight will be more readily seen than a surface parallel to the line of sight.

D. Transition Spaces

Special care should be taken in the lighting of exterior-to-interior transition spaces to reduce problems of eye adaptation that results from high contrast areas. This can be accomplished in some cases by using high-reflectance wall, floor, and ceiling surfaces, as well as by the placement and quantity of illumination.

E. Color

Finish colors are affected by the light source color; finish colors and light source colors should be compatible with one another. Light source colors used throughout the system should be in the warm end of the spectrum, such as the following:

1. Fluorescent—warm white
2. Mercury vapor—deluxe white

F. Brightness and Glare

Glare from transit station light sources or reflective surfaces must be reduced to an absolute minimum such that it in no way affects the vision of motorists.

Light spill must also be prevented from the stations onto the roadways and areas adjacent to the stations and station sites.

Reduce brightness and glare to an absolute minimum, as follows:

1. Minimize specular reflection on signing by locating light sources to avoid direct reflection or by selecting anti-reflective finishes.
2. Minimize or eliminate direct glare from exposed lamps and high brightness areas of individual fixtures.
3. Minimize or eliminate undesirable reflections in glazed or polished surfaces, glass, walls, and other similar elements.
4. Minimize or eliminate light spillage onto adjacent properties and eliminate night sky pollution. Use full cut-off luminaires (fixture and lamp design) and low-reflective surfaces.

G. Parking Structures

1. Light sources in a parking structure should not be visible from outside the structure, in particular those of the upper decks.

10.12.4 Vandalism

A. Mount fixtures at least 8 feet, 6 inches above the finish floor in public areas to minimize vandalism. The selection and location of each fixture should be considered with respect to its vulnerability to vandalism.

B. Use vandal-resistant materials and tamper-proof hardware for fixtures and lenses.

10.12.5 Maintenance

A. Locate fixtures so that they are accessible for regular maintenance. Lamps must be easily serviced without the need for special maintenance equipment.

B. Fixtures shall not be mounted more than 20 feet above the finished floor; luminaries shall not be mounted at a greater height.

C. Adequate space and clearances must be maintained for the use of fixture-maintenance equipment.

10.12.6 Lighting Design Review

A. As part of the Preliminary Design submittal, the Station Designer shall provide the following information:

1. A brief statement of the lighting design approach for the specific project. This report should include the aesthetic concept and the requirements to achieve it, as well as a description of any special design features.

2. Lighting layouts for all major areas, including platforms, concourse and entry areas, pedestrian bridges, pedestrian tunnels, plazas, parking lots, and bus loading zones.
3. At appropriate locations on the drawings, the footcandle values for the major areas.
4. Calculations supporting the indicated footcandle values, keyed to the specific areas on the plans to which the calculations apply. Where the design of a space creates non-uniform illumination levels, calculations of both the maximum and minimum levels shall be provided.
5. A preliminary lighting fixture schedule and any special lighting fixtures proposed.

B. As part of the pre-final design submittal, the Station Designer shall provide the following information:

1. Lighting layouts for all areas, including non-public spaces.
2. At appropriate locations on the drawings, the footcandle values for all areas, including non-public spaces.
3. Calculations supporting the indicated footcandle values, keyed to the specific areas on the plans to which the calculations apply. Where the design of a space creates non-uniform illumination levels, calculations of both the maximum and minimum levels shall be provided.
4. Calculations demonstrating that emergency lighting in all station areas traversed by emergency exitways comply with Chapter 20, Facilities Electrical.
5. Mounting details for all fixtures in public spaces and for unusual conditions in ancillary spaces.

10.13 SIGNING AND GRAPHICS

10.13.1 Introduction

This section lists the main principles and basic requirements for signing and graphics throughout the system.

A system of symbols/pictograms will be established to identify each station in the system for informational signs

Electronic display signs (variable message signs) are required in all stations to provide train information as well as limited advertising messages. In addition, the electronic display signs will provide equivalent public information to the hearing impaired.

The platform edge light assembly shall be designed to incorporate the electronic signing system directly.

Art work shall be coordinated with signing to avoid conflicts.

10.13.2 Basic Goals

A. To guide patrons through the system in the most efficient and least complicated manner.

B. To provide orientation and information required by the patron to aid directional decision making.

C. To provide a safe trip for patrons and to warn patrons and non-patrons of potential system hazards.

D. To provide a fast and safe exit in case of emergency.

E. To allow patrons to know where they are and where they are going at all times.

10.13.3 Types of Signage

A. Directional and wayfinding signage

B. Informational signage

C. Safety signage

D. Operational signage

10.13.4 Definitions

A. Directly Illuminated

A sign for which special external illumination is required.

B. Fixed Sign

A sign with a set format that remains constant through all applications.

C. Indirectly Illuminated

A sign that is illuminated by ambient light. No special means of illumination is needed.

D. Internally Illuminated

A back-lighted sign with its own internal illumination.

10.13.5 General Requirements

A. The design of signs and graphics shall be based on the *Manual of Graphic Standards* for the system and will be uniform throughout the system.

B. As the individual station design is developed, a signing layout will be prepared by the Station Designer in cooperation with RTD for all signs. Provisions of electrical power, where required, will be the responsibility of the Station Designer, unless specifically noted otherwise.

C. A standard station marker or pylon will be used to identify each station entry. Where pylon installation is not possible, provision will be made for a suitable station identification marker. There shall be a minimum of one pylon or station marker per entrance. The location is to be visible from at least two cross streets or roads bisecting the station entrance so that patrons will recognize and locate the entrance on approach by foot or vehicle.

D. Messages, type faces, colors, materials of signs, and station identification pylons will be uniform to ensure legibility and clarity of messages for efficient functioning of the overall station, as well as economical purchase of the signs and their long-term maintenance.

E. Signs should be kept to the minimum necessary for passenger guidance. Signs should reinforce architectural elements in identifying entrances, exits, traffic routes, etc.

F. Certain signs will have priority over others, such as signs directing passengers to normal and emergency exits. This priority may be indicated by differences in sizes, color, or location.

G. Signs will have precedence over artwork and advertising with regard to their location and prominence.

H. Signs should occur at key points of separation and at intervals frequent enough to allow patrons to find their way confidently.

I. Signage shall comply with ADAAG and ABA standards, and shall comply with Flammability Standards of the Fire/Life Safety Criteria.

10.13.6 Signing System

Architectural Directive Drawings identify the format of the signing layout to be prepared by the Station Designer.

10.14 SANITATION AND MAINTENANCE

10.14.1 Introduction

This section presents the general standards for station sanitation and maintenance facilities.

A. The maintenance and sanitation concept assumes that the operating authority will provide all necessary maintenance equipment and facilities, regardless of whether the maintenance work forces consist of authority employees or contract personnel.

Maintenance crews will be based at the Maintenance and Storage Facility, and possibly at other off-station locations. Most maintenance equipment, materials, and supplies will be stored in the Maintenance and Storage Facility. Provisions at stations for maintenance personnel and for storage of equipment, materials, and supplies will therefore be the minimum necessary.

B. Station maintenance activities are classified under three general categories:

1. Inspection and service

2. Preventive maintenance

3. Corrective maintenance

Work under the first two categories will be performed on a prescheduled routine basis. Work under the third category will be provided on an as-needed basis.

C. Most station maintenance activities will be performed during revenue hours. Only those activities that would seriously disrupt revenue operations will be performed during non-revenue hours.

10.14.2 Basic Goals

A. To create easily maintained environments with high level of cleanliness throughout the system, which will instill pride and encourage use of the system.

B. To provide facilities for an efficient maintenance program that operates at minimal cost.

C. To integrate maintenance elements in the stations as part of station design without detracting from the appearance of stations.

D. To provide uniform interchangeable facilities within each station, or between stations where possible, to facilitate replacement of damaged items.

10.14.3 General Principles

A. Maintenance and operation programs requiring the use of trainway areas and equipment should be avoided. Although some intrusion into the trainway may be necessary, each occasion will cause additional programming problems with revenue operations or high cost for providing services for limited times during premium hours.

B. Horizontal ledges should be avoided to minimize the collection of dust. Wherever possible in above grade stations, the exposed top surfaces of outriggers, beams, parapets, and window ledges shall have a minimum slope of 45 degrees to horizontal to prevent the collection of dust and debris and to discourage birds from roosting in station structures.

C. Bases should be flush with walls or recessed. If recessed, the configuration must not preclude the use of a vacuum scrubber to clean the floor within the recess. Provide cove base, integral with floor, not less than 6 inches high at all points of intersection between floors and walls, partitions, columns, and other surfaces in all public areas, as well as in toilets and custodial, trash, and battery rooms.

D. All station facilities and amenities should be designed and located to require limited maintenance.

E. Signs, advertising panels, and artwork should be designed and located to require limited maintenance.

F. Cleanouts and access panels should be located inconspicuously and, where possible, placed in pipe chases and nonpublic areas. In public areas, panels shall be provided with locks.

G. Mounted items of equipment, including movable equipment, should be flush. Such equipment must be accessible to the disabled, including those in wheelchairs.

H. Notches in walls for flush-mounted equipment should not extend down to the floor unless necessary to provide access for the disabled. Bottoms of such notches should be not less than 6 inches above the adjacent floor at any point. Where equipment is freestanding, it should have its own integral base fitted tight to the floor. Where equipment is grouped, flush closure strips should be used to cover spaces between units.

I. The placement of structural and architectural elements that project from walls shall comply with ADAAG. Verify that floor and wall surfaces below or adjacent to the projecting element are accessible for cleaning.

J. Signs, handrails, benches, and other similar elements should be securely anchored with tamperproof screws or bolts. If heads must be exposed, use flush spannerhead screws. Use Allen-head screws if heads are concealed from view.

K. Duplex receptacles for maintenance at the platform area shall be installed along the windscreens at center platform stations and the parapet wall at side platform stations. They shall have a spring-loaded cover.

L. Separate trash receptacles are to be provided for normal refuse, recyclable newsprint, or other items at designated locations.

10.14.4 Specific Requirements

A. Entrance

1. Provision should be made at each entrance for a 110-volt AC weatherproof outlet and a ¾-inch hose bib in adjacent locked stainless steel cabinets.
2. Trash receptacles should be located at all entrances, bus drop-off areas, kiss-and-ride areas, transit centers, and park-and-ride lots.

B. Concourse

1. Pairs of utility outlets consisting of a ¾-inch hose bib and a 110-volt AC waterproof outlet shall be provided throughout public and ancillary spaces, and located so that no portion of the floor area is more than 100 feet from such a pair. Pairs located in public areas shall be installed in a flush-mounted, two-compartment stainless steel cabinet: one compartment containing the hose bib and the other compartment containing the electrical outlet.
2. Trash receptacles should be located at key points where people stop, such as at vending machines, fare gates, and seating areas. Trash receptacles will be furnished on a systemwide basis.

C. Janitor Room

These rooms shall be located close to the elevators. Items in this area will include the following:

1. Mop sink: 36 inches x 24 inches, floor-mounted with 6-inch-high rim and stainless steel rimguard, waste connection fitting.
2. Hot and cold water, single spout with pail hook at 3 feet 0 inches above the bottom of the mop sink, equipped with 4 foot, 0 inch length low-pressure hose.
3. Floor drain.
4. 110-volt AC waterproof outlet directly adjacent to scrubber storage space.
5. Two adjustable shelves 10 feet 0 inches minimum by 1 foot 0 inches deep for storage of cleaning supplies and similar items.
6. Two adjustable shelves 6 feet 0 inches minimum by 1 foot 6 inches deep for storage of toilet supplies and similar items.
7. Ten sets of stainless steel cam-action tool holding clips.
8. Space for double bucket and vac-scrubber machine.

D. Trash Room

This room is to be located at-grade close to the elevator.

Items in this area should include the following:

1. 110-volt AC weatherproof outlet.
2. Cold-water hose bib, 3 feet 0 inches above the floor.
3. Floor drain under the hose bib.
4. Ventilation: Provide mechanical ventilation per Chapter 19, Facilities Mechanical.
5. Sprinkler system: See Chapter 23, Fire/Life Safety.
6. An access door 3 feet 6 inches by 7 feet 0 inches.

E. Platform

1. Provide hose bib and electrical outlets.
2. Fire hose cabinets.

10.15 STATION CONTROL

10.15.1 Introduction

This section describes the supervision, administration, security, and monitoring requirements of stations and how they may be accommodated in the station design as presently anticipated.

10.15.2 Basic Goals

A. To provide for public safety.

B. To ensure efficient operation of the station and to provide optimum service to patrons.

C. To deter crime and vandalism.

D. To accomplish the above with a minimum of manpower by using automatic devices and remote-control equipment.

10.15.3 Planning Considerations

A. General Considerations

1. Stations shall operate with station managers who will monitor CCTV, passenger assistance telephones, and public address systems.

2. The station design should eliminate nooks, recesses, and places to hide, wherever possible, to minimize surveillance problems. Stations should be secured at their outermost points.

B. Aerial Stations

1. Design of passenger stations shall be open, with long, unbroken lines of sight that eliminate all dark or obscure areas.

2. Any equipment or surfaces accessible to the public, such as fare machines and emergency or passenger assistance telephones, shall be of rugged, vandal-resistant design.

   a. Means shall be provided for two-way voice communications. Refer to Chapter 15, Communications and Control.

   b. Illumination levels shall be selected to maintain the level of security in stations at night. Non-operating illumination shall be of the level required to support CCTV surveillance (refer to Chapter 20, Facilities Electrical).

10.15.4 Fare Collection

A. General

The basic location and quantities of future fare gates will be provided by RTD as part of the preliminary design of the stations. The planning dimensions given herein are the minimum required to provide adequate overflow space for emergencies in case of equipment failure or crowding. Initially, an honor system will be in place for proof of payment.

All patron fares will be checked at entry throughout the system, after the initial honor system period. Such checking will be done automatically by fare gates allowing those with valid tickets to enter into the paid area. Exiting will be free.

B. Ticket Vending Machines

Space shall be provided for ticket vending machines in the free area of the station.

1. Sufficient space must be provided within the station area for the ticket vending machines.
2. Vendors within the free area shall be placed to serve incoming patrons; they will not normally be used by those exiting.
3. Vendors shall be clearly visible on entry to the station but placed so as not to impede the direct flow between the station entrance and the fare gates.
4. Fare vending areas for each fare gate shall be provided.
5. Space shall be provided for ticket vending machines as shown on the Architectural Standard Drawings.
6. The required queue space for vendors is 8 feet 0 inches.
7. Provisions shall be made for the electrical requirements for all vending equipment.

C. Fare Barriers

Provisions for fare gates and fare barriers shall be included in the design of the stations.

1. Heights of barriers adjacent to fare collection gates shall be 3 feet 6 inches.
2. Portions of barriers that may have to be removed in the future to accommodate additional fare gates shall be designed to be removable in modules equal to the width of the fare gate unit.
3. Where bars, slats, or pickets are used, the spacing centerline to centerline shall be 4 inches. Maximum clear opening between the end of the barrier and the fixed wall shall not exceed 3 inches.
4. Barriers shall be non-climbable.
5. Design of the fare collection barrier shall be coordinated with the design of the station closure elements.

D. Fare Gates

All entries and exits to the system will be controlled through gates. Right-hand gates to the entering flow are to be entry gates; the right-hand gates to the exiting flow are to be the exit gates. The entry gates are to be capable of reversible designation to suit the major directional flows. All gates are to be designed for right-hand operation. Conduit shall be provided for future fare collection equipment in the initial station construction, in accordance with the requirements specified in Chapter 20, Facilities Electrical. Initially the system will have an honor system for proof of payment.

1. The number of fare gates is to be determined by RTD.

2. Dimensions of Fare Gates

   a. The approximate dimension of the consoles are 6 feet 6 inches long by 3 feet 4 inches high inches by approximately 11 inches wide; they shall be spaced 2 feet 8 inches on centers (leaving a path approximately 1 foot 9 inches wide).

   b. A queue space of 15 feet 0 inches is required on each side of the fare gates.

3. Emergency Egress at Fare Gates

   All fare gates are to be “free-wheeling” in the exit direction at all times. Emergency exit gates may also be required as part of the fare barrier to accommodate the evacuation of the station occupants.

4. Service/Wheelchair Gate

   a. There must be a single service/wheelchair gate through the barrier, separating paid and free areas of the concourse. This gate may be used by patrons, including a person in a wheelchair, the maintenance and service staff, and emergency crews (police, fire, etc.).

   b. The service/wheelchair gate is to be controlled by equipment similar to that controlling fare gates. A console is to be provided at the gate at a height suitable for operation by a person in a wheelchair.

5. Emergency Exit Gate

   In stations where additional exit capacity is required over that provided by the service/wheelchair gate(s), emergency exit gates may be provided as part of the fare barrier. The need for and number of these gates will be determined by RTD as part of the station preliminary design and reviewed by RTD.

10.15.5 Station Manager’s Booth

A. The station manager will monitor and control the stations. Responsibilities will include the following:

1. Supervision of Passenger Activity

   a. Monitoring and controlling CCTV equipment.

   b. Monitoring fare vending and fare collecting activities.

   c. Providing information and assistance to patrons.

   d. Acting in emergencies, such as illness or assault.

   e. Reversing fare gates and monitoring escalators as required for changing traffic flow.

f. Controlling entrance and exit of special personnel, disabled patrons, etc., via the elderly/disabled gate at fare barriers, when future fare barrier system is operational.

g. Monitoring of elevators.

2. Supervision of Station Operation and Security

a. Monitoring stations for undesirable and illegal acts against patrons, operating authority personnel, and station facilities.

b. Directing the activities of the operating authority's personnel in stations by means of verbal direction, CCTV, and the telephone system. Monitoring station intrusion alarm system and card access system.

10.15.6 Security/Staff Room

A. Each station will have a Security/Staff Room used principally by security personnel. The room should be inconspicuous. The Security/Staff Room shall accommodate a desk and two chairs.

B. The Security/Staff Room in each station shall have the necessary conduit installed to provide CCTV monitoring capability of the individual station.

10.15.7 Station Closedown

A. Security closure gates will be provided. Security gates at each station entrance shall be electric roll-up grilles.

B. Each secured station must have at least one means of emergency egress.

C. Security enclosures shall be located in such a manner as to eliminate places of concealment accessible from the street after closedown.

D. The emergency exit at all stations that is closest to the incoming electrical room shall have a direct ringdown telephone at the base of the exit.

E. To the extent possible, stations shall be open, with clear lines of sight.

10.15.8 Security Alarms and Locks

A. For requirements, see Chapter 25, System Safety and Security.

END OF CHAPTER

Honolulu High-Capacity Transit Corridor Project

(Project)

DESIGN CRITERIA

CHAPTER 11

LANDSCAPE ARCHITECTURE

May 22, 2009

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11.0 LANDSCAPE ARCHITECTURE

11.1 GENERAL

11.1.1 Introduction

A. Creating an inspired ground plane with landscape planting, paving, and furniture plays a major role in defining this transit system's place in Hawaii. It is of vital importance that a project of this magnitude has strong character, identity, and relevance to all of the communities that it connects, as well as to the State of Hawaii at large. The landscape architectural design components are a key part to linking character and unifying the miles of guideway and stations. The patron experience is enhanced through the use of design elements, public art, landscaping, and lighting.

B. By repeating elements of the design in all stations, unity will be forged. By varying material selections based on community context, relevance will be achieved. The Station Designers shall follow this Chapter to help create in a coherent and meaningful way a one-of-a-kind transit system that will make Hawaii proud. The Design Book explains that in Hawaiian inspired landscape planting design is more important than in any other transit system in the world."

C. This criterion is intended to unify the system-wide approach to landscape design and to reflect the unique climate, history, culture, and environment in which this project is set.

11.1.2 Goals

A. The basic goal of these criteria is to ensure the public welfare by providing project facilities that do not compromise the health and safety of the public or the users of the system.

B. Embody Hawaii and Honolulu's rich cultural heritage in the form, material selection, and arrangement of the system's landscape architecture.

C. Contribute to the system's functional identity through the use of repetitive elements of design and their arrangements.

D. Enable context-sensitive site designs that are functionally integrated and culturally expressive of their specific locations.

E. Help to mitigate the visual impacts of the system's facilities, stations, guideway, traction power substations, parking lots and structures, maintenance facilities, etc.

F. Comply with the principles of Crime Prevention through Environmental Design (CPTED). Contribute to the safety and security of all passengers.

G. Achieve a high level of environmental sustainability by substantially reducing potable irrigation water usage requirements, reducing demand on traditional energy sources, specifying materials and elements that require minimal maintenance, and reducing site disturbance.

11.1.3 Reference Data

A. Street Trees Technical Report

This technical report by the City and County of Honolulu Department of Transportation Services Rapid Transit Division (RTD), in cooperation with U.S. Department of Transportation Federal Transit Administration (FTA), identifies the foreseeable impact on street trees along the guideway alignment for the alternatives. A certified arborist compiled the street tree survey and the arborist's evaluation is included in this report, as well as an inventory of notable and exceptional trees. Station Designers will mitigate impacts to these urban forest resources as a part of the landscape design of the system.

B. Design Aesthetics

Station Designers and Station Architects will be furnished with a Design Language Pattern Book that they will use to guide and inform their landscape architecture design solutions.

C. Station Scope of Work

This document outlines the work of the Station Designer and includes stages of design, submittals, budget, and schedules.

D. Utility Locations

Utility drawings for the various sites will be made available by RTD or its designee. Tree setbacks should comply with the City's *Standards and Procedures for the Planting of Street Trees*.

E. Other General Data

1. Master plans, urban renewal plans, and plans for specific future projects, in the area of influence for a particular station, shall be reviewed for pertinent information that might influence site development and design possibilities.

2. The following contextual station planning data shall be provided to the Station Designers by RTD in the form of the following reports and guidelines:

    a. Station Area Interface and Access Report

    b. Transit System Urban Design Guidelines

    c. Archeological resources Technical Report

    d. Cultural Resources Technical Report

    e. Street Trees Technical Report

    f. Sustainable Community Impact Report

    g. Station Area Development Potential Report

F. Definitions

1. *Berm*: An earthen mound designed for visual interest, buffer, or screening.

2. *Buffer*: A combination of physical space and vertical elements, such as plantings, berms, fences, or walls, whose purpose is to separate and screen adjacent incompatible land uses.

3. *Exceptional Tree*: A tree or grove of trees with historic or cultural value, or which by reason of its age, rarity, location, size, aesthetic quality, or endemic status has been designated by the City Council as worthy of preservation (per the Revised Ordinance of Honolulu, Section 41-13.2 1990).

4. *Landscape Architect*: Individual or firm who is responsible for station landscape architectural design.

5. *Notable Tree*: A tree deemed to be significant to the urban landscape character (per the *Street Trees Technical Report, 2008*)

6. *Ornamental Tree*: An accent tree usually under 20 feet in height that is planted for its showy flowers, foliage, or bark.

7. *Screen*: A vertical element of plants, berms, fences, or walls that blocks the visual appearance of an undesirable view or incompatible land use or mitigates the noise impact of an adjacent roadway or other land use.

8. *Shade Tree*: Usually a medium-to-large broadleaf tree with a mature height of more than 20 feet and planted primarily for its high crown of foliage or overhead canopy.

9. *Shrub*: A woody plant, smaller than a tree, consisting of several small stems from the ground or small branches near the ground.

10. *Specimen Tree*: A particularly impressive or unusual example of a species due to its size, shape, age, or any other trait that epitomizes the character of the species.

11. *Xeriscape*: The use of drought-tolerant plant species in the design of a landscape. Low water use does not indicate no water is required.

G. Applicable Codes and Standards

1. The design of the stations shall comply with all Federal, State, and Local codes.

2. These codes and standards shall, in each instance, be the most recent revision, amendment, or supplement adopted by the Federal or State or as administered by the City at the date of notice to proceed with the final design of each specific project, or as directed by RTD.

3. With the exception of the variances described herein, where the requirements of more than one code or standard are applicable, the more restrictive shall govern.

H. Codes, Regulations, and Standards

1. City and County of Honolulu, *Development/Sustainable Communities Plans* http://www.honoluludpp.org/Planning/DevSustCommPlans.asp

2. U.S. Green Building Council, *LEED® for New Construction and Major Renovations* (version 2.2 or later)

3. American Association of Nurserymen, *American Standard for Nursery Stock*, ANSI Z60.1 (2004 or later)

4. University of Hawaii at Mānoa, *CTAHR Landscape Publications* http://www.ctahr.hawaii.edu/ctahr2001/PIO/FreePubs/FreePubs06.asp#Landscape

5. Sustainable Sites Initiative, *Preliminary Report* (2007 or later) http://www.sustainablesites.org/report.html

6. Hawaii Chapter American Society of Landscape Architects (ASLA Hawaii), *Invasive Species—Do Not Plant List* (2007 or later) http://www.lichawaii.com/invasive_species.htm

7. City and County of Honolulu Department of Planning and Permitting, *Standards and Procedures for the Planting of Street Trees* (1999 or later)

8. Irrigation Association, *Turf and Landscape Best Management Practices* (2005 or later) http://www.irrigation.org/gov/pdf/IA_BMP_APRIL_2005.pdf

9. *Transit Security Design Considerations*, Federal Transit Administration, DOT-VNTSC-FTA-05-02

11.2 DESIGN INTENT

11.2.1 Introduction

The design intent for the system's landscape architecture is to unify the stations and approaches by use of a limited shrub and groundcover palette, and to create variation primarily in the paving colors and tree selections. By applying these principles in a consistent manner the system will have unity and familiarity to transit patrons and to anyone viewing the system. Layout, texture, and pattern shall have elements of consistency within geographic areas and variation along the alignment. Due to the linear nature of the alignment, effort shall also be made to reinforce landscape expressions perpendicular to the guideway. These expressions may occur at stream crossings, major roadways, parks, or fragments of land owned by the City or State.

11.2.2 Basic Goals

A. To create a timeless design for the landscape architecture that is relevant to Hawaii's history, culture, climate, and future.

B. Use of high quality materials in limited amounts to emphasize the station approaches and other important features, while maintaining a reasonable construction budget.

C. Focus on the natural shape and character of materials rather than man-made or manufactured shape of materials.

D. Enhance the perception of safety, security, and comfort.

E. Treat specialty stations with historic context and careful design to reinforce the uniqueness of context or use (e.g., the Kapālama Station should have a special planting of True Kamani trees).

F. Accentuate the mauka-makai relationship of streams and other perpendicular crossings to add character, variety, and scale to the alignment.

G. Magnify the ahupuaʻa and regional characteristics through the landscape architecture.

H. Transplant as many trees as possible displaced by the guideway to other areas of the Project that will be part of the first phase of construction or will otherwise not be disturbed by later construction. Repurpose wood from any trees that are not able to be saved or salvaged and transplanted.

11.2.3 Philosophy

A. The community is an integral part in the design process. Involve them through public meetings and use their input. Use context-sensitive solutions, development and sustainable community plans, buffering, connectivity, materials, and colors to integrate the rail system into the local context. This facility and its design serve as an amenity to the community.

B. Address landscape as a functional resource to the transit corridor. The urban forest provides benefits of clean air, shade, cooling, and erosion control at a reasonable cost.

C. The safety and security of rail passengers is of the utmost importance. Appropriate lighting, visibility, clear view of closed circuit television cameras and CPTED guidelines should be incorporated into each station area design.

11.2.4 Crime Prevention through Environmental Design (CPTED)

CPTED focuses attention on altering the physical environment (e.g., spatial definition, location, adjacent uses, and transparency) rather than operational means of security (e.g., guards or shift work) or mechanical means of security (e.g., alarms, cameras, and fences) to influence behavior. While there still may be a need for other methods of security, changing the design of the physical environment is typically the most cost-effective and longest lasting. Landscape design elements shall not compromise other types of security measures such as closed circuit television, public address systems, and intrusion-detection systems.

> "The physical environment can be manipulated to produce behavioral effects that will reduce crime. These behavioral effects can be accomplished by reducing the propensity of the physical environment to support criminal behavior." – Timothy Crowe, CPTED

A. CPTED Concepts

1. *Natural Surveillance* refers to the opportunity for people and their activities to be readily observed by the general public or law enforcement during regular patrols. This can be accomplished by actual observation or the potential observation from adjacent windows or frequently populated areas.

2. *Natural Access Control* uses design to clearly define public and private areas or restricting access using natural boundaries. Unintended users are easy to identify because public versus private spaces are well defined. Entries should be clearly visible and easy to find so that first-time users or visitors can walk confidently.

3. *Territorial Reinforcement* refers to when design elements such as paving, planting or low walls are used to demarcate property ownership or to expand a property's influence over a public sidewalk. Clearly demonstrating ownership or care for an area gives behavioral cues to engender respect.

4. *Maintenance* is an ongoing component to reducing crime. Taking regular care of the property conveys ownership and presence on the site, which discourages unwanted behavior.

B. CPTED Strategies

1. Keep a natural surveillance "window" open between 2 feet and 7 feet high. Except where required by code, this window should be free of plantings and solid barriers, but may include transparent barriers.

2. Advertising or other types of obstructions on transparent partitions should be limited to 50% and always should allow for visibility at 1 to 2 feet above the ground.

3. Use planting and paving materials to clearly define ownership, main entries, and to help identify intended users.

4. Minimize confusion in locating points of entry and common destinations in the platform area. Regular users or tourists that appear to know where they are going and walk confidently are less likely to be assaulted. Make strategic use of wayfinding elements, colors, materials, lighting, and other design elements to increase definition, clarity, and visibility.

5. Separate and/or buffer conflicting activities with natural barriers or site elements.

6. Use the scheduled activities to design spaces with an appropriate level of intensity of use. Areas for queuing near bus or train doors have a higher level of intensity compared to waiting areas off to the side.

7. Since public spaces are the hardest to defend, create "transition zones" that are perceived as semi-public. As an intruder transitions into the semi-public space it is easier to identify, deter, defend, and prevent crime.

8. Gathering areas that will naturally attract people should be placed near potential crime areas to promote natural surveillance. Likewise, place unsafe activities in easily observed areas such as below balconies or walls with many windows to reduce vulnerability.

9. Use elevation to its advantage to celebrate entries or to distinguish semi-public spaces from public areas.

10. Create clear and open sight lines near exits, stairwells, structures, artwork, or any potential hiding place. Eliminate possible areas for ambush and use obtuse angles where visibility is limited to reduce the opportunity for concealment.

11.2.5 Sustainability

A. Site design should respond to the unique climate of O‘ahu and adhere to sustainable design principles of water conservation, soil conservation, energy conservation, and human resource conservation (i.e., low maintenance landscapes). Station Designers should favor simple, sustainable solutions rather than overly complex and costly solutions. Refer to Chapter 26, Sustainability, for further details.

B. Use the latest standards of sustainable land development, treatment of soils, selection of materials, and installation practices to set the example of sustainable public infrastructure. Reference the Sustainable Sites Initiative and the U.S. Green Building Council, LEED for New Construction documents as a guide to address design innovations and best management practices.

11.2.6 Geographic Areas

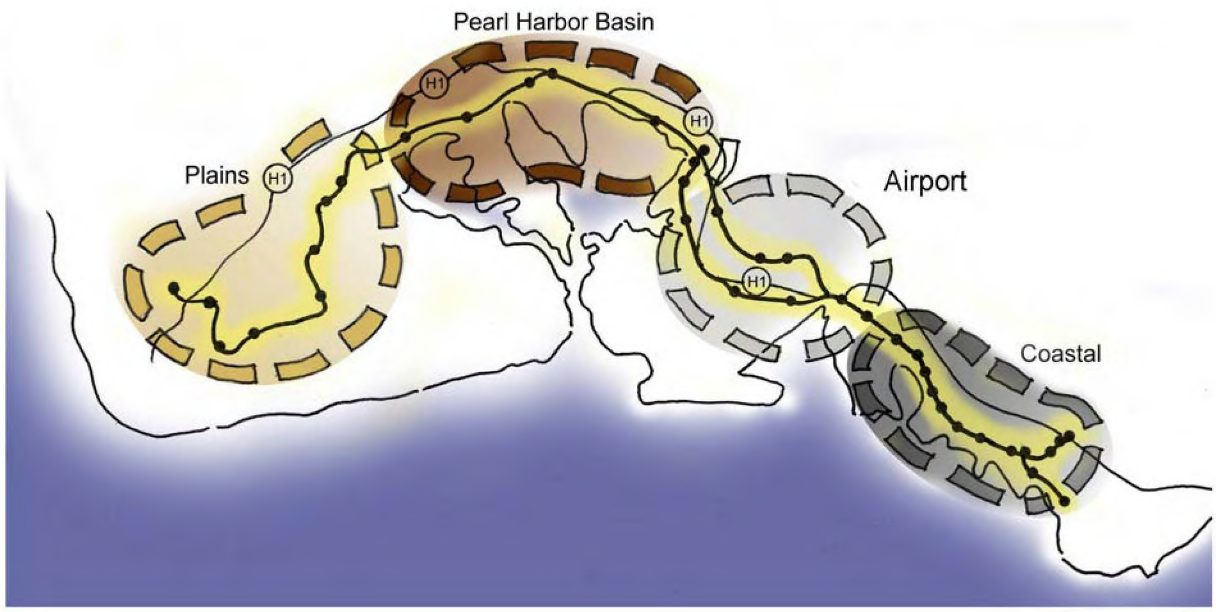
A. The Design Book refers to the inspirational nature of the ahupua‘a as one that should inform the transit design. Since there are many ahupua‘a that cross the transit alignment, the system will also view these divisions within the larger geographical areas. These geographic areas are timeless, having the same relevance and identity today as they did in historic times. The alignment is described by the following geographic areas: The Plains, Pearl Harbor Basin, Airport, and Coastal, as shown in Figure 11-1.

B. The Plains is defined by the broad sloping terrain built on coral beds with few trees, much sun, and little rain. In this area with few natural resources, the ahupua‘a is quite large, incorporating several transit centers within one ahupua‘a.

C. By contrast, the Pearl Harbor Basin has several ahupua‘a, with the rich nature of water, soil, and coastal resources. In this geographic area it is common to only find one transit station per ahupua‘a. Most of these ahupua‘a have the word “wai” for water included in the name, which speaks to this abundant resource. Soil in this area is equally rich, with a characteristic reddish brown color.

D. The Airport area is more arid than the Pearl Harbor Basin, named after a naturally occurring saltwater body separated from the ocean. Airport is home to a layered shale rock in tones of gray to almost white. This geographic area contains the Airport Spur that will be the welcoming statement to many island visitors. Two high-capacity stations are located within this area: Airport and Aloha Stadium.

Figure 11-1: Geographic Areas



E. Finally the Coastal area encompasses Downtown Honolulu and Waikīkī, which is rich in resources and is typified by the deep charcoal or black color associated in Hawaiian culture with fertile soil. The richness of the coastal area also refers to the richness of cultural activity, including the historical use of this area for relaxation, surfing, and hula.

F. These geographic areas in Figure 11-1 will be used as the basis for informing the paving color choices, as well as the planting palette.

11.3 ZONES

11.3.1 Streetscape

The in-line, at-grade areas between stations is the streetscape. Street tree planting or transplanting will occur adjacent to the station area and along the alignment where the existing streetscape is impacted. Trees should be placed every 50 feet where adjacent to residential areas and every 40 feet where adjacent to commercial areas. Tree species, sizes, and details must conform to City standards.

Tree grates or other accessible surfaces should cover over the planting area if the sidewalk hardscape surface is less than 6 feet wide. Trees must be planted a minimum of 3 feet away from curbs and a minimum 2 feet away from the edge of walkways.

11.3.2 Station Areas

A. Approaches

1. Planting and paving design play a pivotal role in increasing station visibility and identity, as well as directing patrons to the station entry. Entries shall be highlighted with paving and planting materials as directed. The design of the station approaches

shall link the entry plazas to bus drop-off lanes and public walkways in creative ways that allow for pedestrian circulation, seating, and queuing.

2. Good visibility is important for traffic safety and security concerns. Low shrubs and groundcover should be used in station areas near bicycle or vehicular traffic to increase visibility.

3. Provide shade in station entries and approach areas for user comfort.

4. Select an identifying street tree to use in station approach. Palms also may be used as vertical accents, especially where horizontal space is restricted.

B. Concourse and Platform

In some locations it may be advisable to add planters to soften the station architecture. On the concourse and platform areas this will not be a standard feature throughout the transit system but decided on an individual basis.

C. Pedestrian Crossings

Clear visibility is of the utmost importance for traffic safety concerns. Trees shall have a minimum 7-foot clear trunk height, and shrubs and groundcover should be specified for a mature size of less than 2 feet in height.

11.3.3 Transit Centers and Bus Stops

A. Transit centers serve as transfer stations between buses and trains. Pedestrian and bicycle circulation shall be separated from bus and train traffic to the extent possible.

B. Where bus stops are co-located with transit stations every effort shall be made to provide 100% shade of the bus queuing area with trees rather than structured shade to create a balancing character to the station approach. Where bus stops are located below the guideway or station a minimum walkway width shall be maintained clear of furnishings to facilitate pedestrian circulation. Seating may be located along the wall facing the bus stop of the touch down structure. All plantings will maintain clear visibility, even at maturity, at all pedestrian and vehicular intersections.

C. Provide a minimum of 50% shade on all roadway and paved surfaces. Shade trees shall be planted with 40-foot spacing along road frontage. Trees must be of 2-inch caliper and 10 foot height or greater. Screen transit area to the extent possible from adjacent streets by a 42–inch-high continuous hedge, berm, or solid wall or combination thereof.

11.3.4 Park-and-Ride and Adjacent Parking Areas

A. In parking lots with more than 10 spaces, 1 shade tree with a minimum 2-inch caliper, 10-foot clear trunk is required for every 6 parking spaces or fraction thereof. Where 30 or more parking stalls are contiguous, islands parallel to the drive aisles are required to be a minimum of 6-inch width. Planted islands that are parallel with parking spaces shall be included for every 10 parking stalls and a minimum width of 9 inches. Shade trees and those with average-to-low litter are preferred in park-and-ride parking lot areas to be placed to distribute shade evenly across the lot.

B. Parking lots shall be screened from adjacent streets by a continuous hedge, berm, or solid wall or a combination thereof per City standards.

C. The main pedestrian access from the parking area to the station entry shall avoid crossing vehicular circulation wherever practicable. Pedestrian safety is of utmost importance.

11.3.5 Traction Power Substations

A. Traction Power Substations are structures that redistribute the electrical current needed to run the rail system. Placed at regular intervals along the alignment, these structures are typically one story, windowless, and approximately 40 feet by 80 feet. They typically have vehicular access along one end and pedestrian access on a side perpendicular to the vehicular access.

B. Maintain a minimum 5-foot width clear access around all sides of the structure.

C. Use tall vertical planting or vines to visually screen or minimize the impact of the structure. Plants or vines should be a minimum of 6-foot height in secure areas while maintaining visibility to the entrances.

11.3.6 Under Guideway

Where the guideway columns fall within curbed areas, vines may be trained onto columns to reduce the likelihood of graffiti and soften the appearance of the structures. Surface texture of the column design may be enhanced to facilitate vine attachment and growth. Shade-tolerant ground cover shall also be specified for the median planter, where applicable.

11.4 PAVING

11.4.1 Introduction

A. The purpose of this section is to describe the paving and hardscape elements at the ground plane in station areas. Along with the plantings, paving design is integral to the identity and patron experience of the transit system. Paving should not only be practical and affordable but also relate to the Hawaiian sense of place and cultural context.

B. Paving at ground level needs to be compatible with the concourse and platform levels. The primary objective of the paving is to relate to other platform entry areas, both system-wide and in defined geographic areas.

11.4.2 Basic Goals

A. Ground-level paving shall express the ahupua‘a or geographic area through the use of specified colors and use pattern or form to provide unity throughout the stations.

B. Station-entry paving shall evoke the character of the ancient arrival sequence, an open, flat, welcoming entry clad in pavement symbolic of the indigenous land. Naturalized or random layouts are generally preferred over man-made or machined forms to convey the natural basis of Hawaii’s setting and to create a timeless character.

C. Where possible, paving shall be increased beyond the immediate station entry to address the CPTED concept of expanding the influence of the station and its secure environment into the community to deter unwanted behavior and provide visual clues to the station's presence.

D. Provide adequately sized paved areas for pedestrian circulation, queuing, and waiting areas adjacent to stations, transit centers, and park-and-ride facilities.

E. All paving materials shall be slip-resistant and free from tripping hazards. Designers shall make every effort to reduce the impact of differential settlement over time. Materials shall be selected with safety, durability, and economy in mind, as well as relevance, comfort, and attractiveness.

11.4.3 Design Character

A. For each of the geographic regions identified in Figure 11-1, the Station Designer shall base paving choices on the color palette defined for each area.

B. The Plains

1. Land Character: Open plain with distant views to ocean and mountains.
2. Stone/Earth: Coral prevalent in area. Incorporate coral within the station's walls, pavement, and furniture.
3. Colors: Buff to golden tones.

Figure 11-2: Color Palette for the Plains

C. Pearl Harbor Basin

1. Land Character: Ahupua‘a subdivisions sloping gently to Pearl Harbor Basin.
2. Stone/Earth: Reddish field stones and red dirt prevalent in area. Incorporate reddish field stone within station’s hardscape (walls, pavement, and furniture).
3. Colors: Warm reds, reddish browns.

Figure 11-3: Color Palette for Pearl Harbor Basin

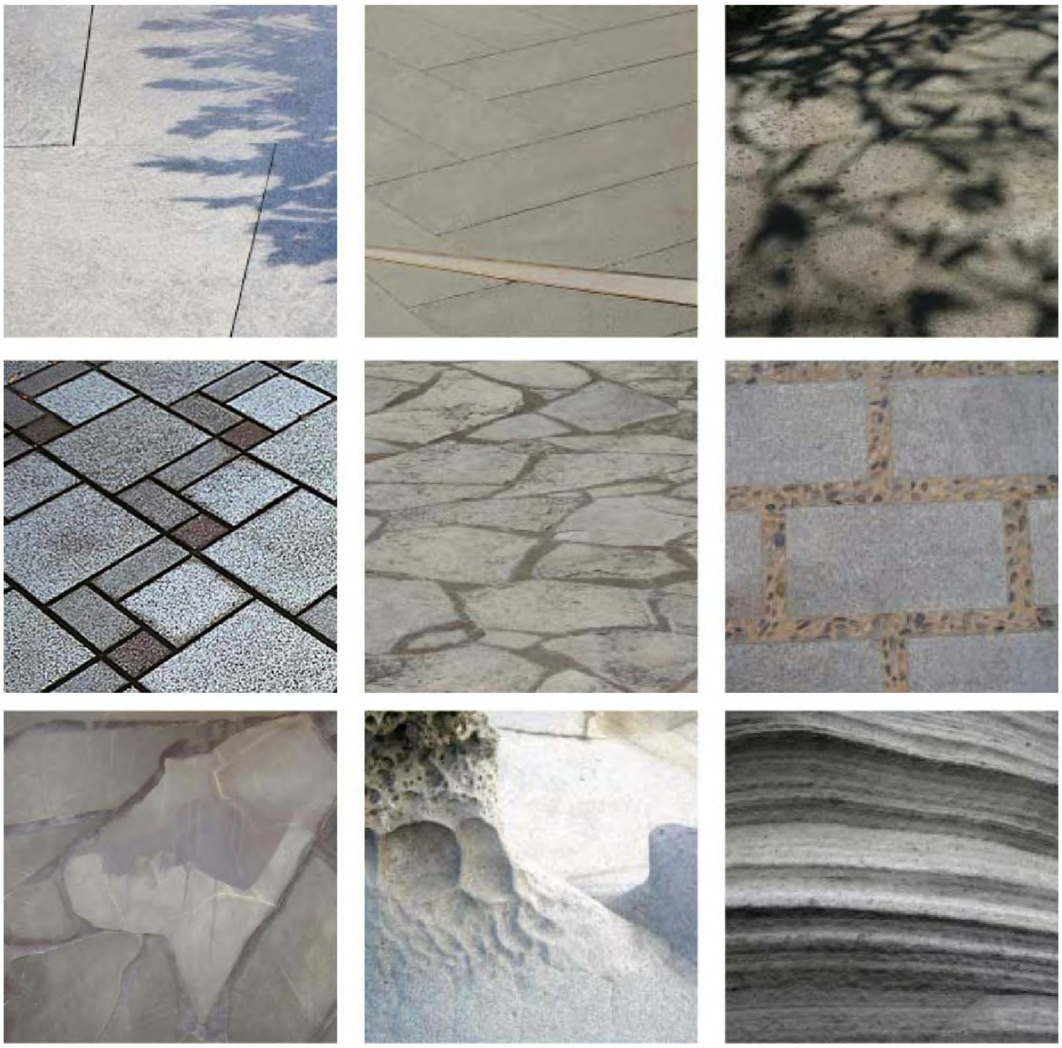
D. Airport

1. Land Character: Ahupua'a slope to ocean interrupted by Airport basin.

2. Stone/Earth: Volcanic tuff that erupted through coral beds (prevalent in the area). Incorporate volcanic tuff appearance within station's hardscape (walls, pavement, and furniture).

3. Colors: Light gray, white, striations.

Figure 11-4: Color Palette for Airport



E. Coastal

1. Land Character: Ahupua'a subdivisions sloping gently to ocean.
2. Stone/Earth: Black/gray fieldstones and dark, fertile soil prevalent in area. Incorporate black/gray fieldstones within station's hardscape (walls, pavement, and furniture).
3. Colors: Dark charcoal gray, black.

Figure 11-5: Color Palette for Coastal

F. Site Furnishings

Integrate bench walls or seat walls for bus stops or queuing areas at the ground level where adjacent to station entries. Integrate site furnishings, such as seating, rubbish bins, ash-trays, bike racks, newspaper boxes, and lighting, as part of the landscape and urban design of the streetscape, approaches, and station areas.

11.5 PLANTING DESIGN

11.5.1 Introduction

A. Planting design can transform and connect the transit system to the land and culture of Hawaii. By using a landscape such as the welcoming coconut grove or planting green ti leaf clusters at specific station entries, landscape design greets transit patrons and roots the station within the urban and suburban context.

B. The challenge is maintaining a high quality of design and experience while recognizing the finite resources of maintenance funds, CPTED principles, labor, and the limited land resources available to RTD.

11.5.2 Basic Goals

A. Enhance the patron experience by providing shade along walkways and queuing areas. Use plant material to provide human-scale elements and soften the elevated fixed-guideway and platform to help integrate the appearance of transit facilities.

B. Create site-specific designs that provide station identity and respond to site conditions, including views, trees, sun and wind patterns, and soils that still relate to the design family of other station areas.

C. Provide a low-maintenance planting design that is attractive and environmentally sustainable.

11.5.3 Character

A. The overall landscape character will be one of ease and simplicity. The landscape design shall be created from a limited plant palette to reinforce unity and continuity from station to station. Some variations will be evident in the paving patterns and colors that will relate to the four geographical areas (Figure 11-1). High-profile stations may include a welcoming coconut grove in an area adjacent to the station to evoke archetypical images referenced in the system’s Design Language Pattern Book. In some cases, a nearby existing park or open space may serve as the coconut grove rather than on the transit site itself. High-profile stations include the Convention Center, Downtown Station (Honolulu), Honolulu International Airport, Middle Street, and Aloha Stadium.

B. The natural character of the plants should be evident in the care and maintenance, but the layout should be in deliberate masses, rows, or groves rather than in an informal, individual, random offset arrangement.

C. Mass planting of a single species is preferred over a mixture of multiple species of plants arranged in a composition. Simplify planting combinations by selecting two to five species to use in each planting area and using only one or two street tree species. This will emphasize identity, repetition, and unity.

D. Shrubs shall be selected for their mature size and lack of need for regular pruning. Hedge-row plantings of shrubs or planting in mass is preferred over a random offset arrangement. Mass planting will reinforce the strength of the design while simplifying maintenance.

E. Restrict the use of turf grass to areas that will serve as public gathering or open space such as the coconut groves at the high-capacity stations. Turf requires bi-weekly mowing and typically uses more water than drought-tolerant ground cover.

11.5.4 Design Considerations

A. Context

Station Designers shall create context-sensitive site designs that are functionally integrated and culturally expressive of their specific locations. Planting designs and material selections shall reflect an indigenous understanding of the land accomplished by magnifying the respective differences among the various geographical areas.

B. Function

1. Facilitate quick connections from bus doors to station entry.
2. Maintain open sight lines for security from the station and employee entries to the nearest gathering area, intersection, or public street.
3. Provide shade for pedestrians and patrons of various modes of transit.
4. At mid-block stations, emphasize the entry area by keeping the area free of shrub plantings that may disguise the entry location.
5. Where bus pullout areas are adjacent to the station touch down, keep the center area of the walkway free of plantings. Instead, incorporate plantings with furniture along the building face of the touch down.
6. At stations with park-and-rides, use plantings to shade the pedestrian connection and ornamental plantings to clearly announce the station entry.
7. Facilitate pedestrian circulation to the station entry by keeping the immediate area clear of plantings and focusing on softening the building areas that have little need for access, such as employee-only entrances or windowless walls.
8. Use plantings to mitigate wind funnels created by the system architecture or to cool areas that will flow toward station entries.
9. Plant trees in and around pedestrian entrances, bicycle zones, waiting areas, and areas where there are a high percentage of paved surfaces to reduce reflected heat conditions, cool the microclimate, and provide shelter for pedestrians.

10. Buffer fast-moving vehicular traffic from walkways; soften the urban environment; and screen unsightly areas from intensively used transit patron zones. Reduce noise impacts and control glare through the use and design layout of plantings.

11. Provide a comfortable scale for pedestrians adjacent to large structures. Use the opportunity of shade from an adjacent structure to provide shade to pedestrians, paved surfaces, or other planting beds.

12. Improve visibility through placement of landscape elements to promote natural surveillance of public spaces. Natural surveillance is increasing everyone's ability to see activity that lessens the incidence of crime. This will create defensible spaces and enhance public safety.

C. Existing Trees/Urban Forest

1. The urban forest is a valuable asset. Trees filter and reduce pollutants in the air, produce oxygen, and use carbon dioxide so the existing inventory needs to be maintained, protected, and expanded.

2. The *Street Trees Technical Report* estimated that a number of trees from the existing urban forest will be removed and more trees will be relocated. A majority of affected trees will be able to be relocated, so Station Designers shall reference the inventory and make provisions for specific tree relocations in their plans. A certified arborist shall be consulted to determine the likelihood of survival for each tree being considered for transplanting.

3. Wherever feasible (as determined by a certified arborist), existing trees should be protected in place.

4. Tree protection includes, but is not limited to, the following:

   a. Mulching the root zone with a minimum of 4 inches of cover and overlaying with plywood sheets to protect against soil compaction

   b. Installing and maintaining tree-protection fencing at the dripline or as close as practicable

   c. Minimizing pruning of major structural roots

   d. Any root pruning must be done with clean cuts, no ripping or tearing

   e. Pruning canopy and roots in similar amounts to reduce shock on a tree

   f. Maintaining adequate irrigation to the tree during construction

   g. No stockpiling or storage of materials, vehicles, or equipment within the dripline

5. Salvaged trees shall be planned for permanent planting elsewhere in the project corridor at the time of salvage to minimize the transportation, staging, and storage of large trees. Where feasible, salvaged trees shall be relocated and transplanted permanently to the Maintenance and Storage Facility site.

D. Design Process

1. Visit each site and perform a detailed site analysis prior to beginning design. Factor in all of the site opportunities and constraints, user needs, and environmental considerations, including minimizing the amount of site disturbance. Preserve in-place or salvage and relocate as many existing trees as possible.

2. Cross-reference specific plant information with nursery experts, plant reference books, and professional experience. Consult local extension agents and nurseries regarding the sustainability, suitability, and availability of plant material before specifying.

3. Specify a clear trunk height or minimum 7-foot overhead canopy height where trees are located immediately adjacent to public walkways to keep sight lines clear and eliminate low hanging branches that may cause injury. Avoid weak wooded trees or species that have a tendency toward limb breakage.

4. Use root barriers to protect hardscape elements and utilities if large trees are planted near sidewalks, curbs, or underground utilities.

5. For planting beds, use triangular spacing and specify in the preliminary engineering and final design drawings the dimension between plants on center.

E. Plant Palette

1. The use of native (indigenous and endemic) and proven adapted species is encouraged. Careful consideration must be paid to the water and nutrient requirements of each species, especially if native plants are combined into planting beds with adapted species.

2. The plant palette (Table 11-1 and Figure 11-6) identifies the primary plant species to be used at specific stations or geographic areas.

F. Invasive Species

1. Invasive species cause serious damage to local property owners and to native habitats. They displace native and adapted species that make up Hawaii's ecosystems.

2. The local landscape community is working on a voluntary code of ethics for agreement upon species identified as "likely invasive" in the Hawaiian Islands. For purposes of this project, the American Society of Landscape Architects' Invasive Species List shall serve as a "do not plant" list. (See Appendix A for Hawaii American Society of Landscape Architects Invasive Species List.)

Table 11-1. Plant Palette by Location

Plant Palette	Plains	Pearl Harbor Basin	Airport	Coastal
Trees				
Kou tree	✓			
Rainbow shower tree (Honolulu city tree)	✓	✓	✓	✓
Monkeypod tree (for parking lots)	✓	✓	✓	
Kukui Tree (UH stations only)	✓			✓
Hong Kong orchid		✓		
Gold tree			✓	
Singapore plumeria				✓
True Kamani (for Dillingham Boulevard only)				✓
Palms				
Coconut (for high capacity and Kaka‘ako)		✓	✓	✓
Loulu palm	✓	✓	✓	✓
Shrubs				
Green ti leaf	✓	✓	✓	✓
Naupaka	✓	✓	✓	✓
Yellow hibiscus (color of O‘ahu)	✓	✓	✓	✓
Groundcover				
Ilima papa (flower of Oahu)	✓	✓	✓	✓
Lauae fern	✓	✓	✓	✓
Pohinahina	✓	✓	✓	✓
Vine				
Creeping fig (for Guideway Columns)	✓	✓	✓	✓
Arrowhead vine (for Guideway Columns)	✓	✓	✓	✓

Figure 11-6: Plant Palette

Kukui Tree

Kou Tree

Rainbow Shower

Gold Tree

Hong Kong Orchid Tree

Monkeypod Tree

Singapore Plumeria

Coconut Palm

Loulu Palm

Ti Leaf

Naupaka

Yellow Hibiscus

Ilima papa

Lauae fern

Pohinahina

Creeping Fig

Arrowhead Vine

G. Visibility Triangles

1. For driver visibility of pedestrians and other vehicles, plant material must be restricted in the area called the visibility triangle. No tree shall be planted closer than 30 feet from the projection of the two perpendicular curb lines. The height between 2 feet and 7 feet must be kept clear. Ground cover or low shrubs that will reach a mature height of less than 2 feet may be planted within this triangle. Tree canopies that overlap must be taller than 7 feet to the underside of the canopy. Larger trees may need to be specified near a sight triangle.

2. In other areas where security is a concern, a surveillance window ranging from 2 to 7 feet in height should be maintained for the safety of pedestrians, except where otherwise required by code.

H. Plant Size and Condition

1. Size of plants specified must meet with all local regulations and American Nursery Association standards, ANSI Z60.1, for the species and size specified.

   a. Shade trees along streets and in parking lots: minimum 2-inch caliper, 8-foot clear trunk height, except in areas near traffic signs or signals, then trees shall have a minimum 10-foot clear trunk height

   b. Ornamental trees: adjacent to public walkways—25 gallon/1.25-inch caliper, 8-foot height. Outside of pedestrian/vehicular areas—minimum 15 gallon/ 1-inch caliper, 6-foot height

   c. Shrubs: minimum 1 gallon, 12-inch height

   d. Groundcover: minimum 4-inch pots and 5-inch height (rooted cuttings are appropriate for some species of ground cover with rapid growth rates)

2. Provide specimen quality, matched trees and shrubs grown in a licensed nursery in accordance with ANSI Z60.1. Plants shall be healthy, vigorous stock, free of disease, insects, eggs, larvae, and injuries, abrasions, or disfigurement.

3. Plant materials shall be inspected and tagged at the nursery, then inspected again and approved by the Station Designer or representative prior to planting.

I. Water Use

1. Use xeriscape principles and drought-tolerant species that are proven to be able to survive during harsh summers in the urban environment. In the transit system, plants will be exposed to reflected heat conditions, winds, poor air quality, and compacted soils; therefore, selecting plants that will easily adapt to these conditions is critical.

2. Select plant communities that have similar water requirements to be irrigated within the same zone. One “thirsty” species can often drive the irrigation requirements, while other shrubs and ground cover in the same zone get more water than they need.

3. Maintenance is desired to be low; therefore, Station Designers should select plant materials that will tolerate this level of maintenance.

J. Design with Maintenance in Mind

1. Selecting adapted species that do not require excessive fertilizer, or excessive pruning to maintain their shape and reducing the amount of turf assists in designing low maintenance landscapes. It is important for Station Designers to concentrate on finding the appropriate species for each location.

2. Relating plantings to the site conditions and context improves the longevity of the landscape and reduces maintenance. Careful consideration should be paid to the following:

   a. Conducting a comprehensive site analysis

   b. Performing soil tests and preparing or amending soil for plant requirements according to test results

   c. Properly arranging plant materials to reduce, screen, and absorb unpleasant sound, smells, and views

   d. Separating shrub and ground-cover planting beds from turf areas and providing separate irrigation zones accordingly

   e. Selecting plants by their appropriate size at maturity

   f. Correctly spacing plants based on 75% size at maturity minimum

   g. Arranging plants by sun exposure and irrigation requirements

11.6 SPECIALTY LANDSCAPES

A. Vertical Planting (Trellis or Green Walls)

Planting screens, hedges, vines on trellises, or green walls can assist in defining outdoor spaces, guide patrons toward walkways or entrances, assist in cooling microclimate areas, and be a graffiti deterrent at guideway piers and platforms.

B. Green Roofs

Green roofs might be appropriate in certain locations, especially on low, flat roofs that can be seen from the station platform. Roof canopies that cover the station entrance have the potential for green roofs that would store stormwater and increase infiltration in areas dominated by pavement. This insulative roofing will also lower the ambient air temperature within the structure.

11.7 SOIL

A. Strip and stockpile existing topsoil wherever possible where soil is viable for planting beds. Limit the height of the stockpile to preserve micro-organisms.

B. Soil nutrient testing should be conducted along with soil borings and load bearing capacity analysis. Soil amendments are anticipated in urban areas where imported soils have insufficient nutrients to support healthy plant growth.

C. Consider the plant growing capabilities of the soil in each site area. Some plants thrive in a variety of soil conditions, while others are more sensitive to differences in pH, porosity, organic content, permeability, and available nutrients.

D. Soil compaction in urban areas is common; efforts should be made to reduce or eliminate soil compaction in planting areas. Compaction testing or 24-hour filtration testing should be conducted before plant installation begins (pH testing is also recommended to be conducted by the Contractor prior to construction). Aeration techniques, such as gravel sumps or perforated PVC tubes, should be used where necessary to improve subsurface drainage.

E. For street trees, structural soil that maintains air gaps and drainage required by roots is a good option, although it should be specified in quantities that allow for discounted rates on its specialty mixing process.

F. Topsoil or fill material brought to the site must be inspected and approved to be free of noxious weeds, termites, clay, and other deleterious material.

11.8 IRRIGATION DESIGN

11.8.1 Introduction

A. Proper irrigation design is the second part of a five-part Best Management Practices (BMP) for landscape irrigation as established by the Irrigation Association. The other four parts include quality assurance, proper installation, proper maintenance, and proper management. The Irrigation Association developed these BMPs as a way for stakeholders to protect and conserve their water resources.

B. Proper irrigation is the process of efficiently applying water to the landscape in an economical and sustainable way to maintain a healthy landscape without exceeding the landscape’s water requirements. This starts with proper planning and design.

11.8.2 Basic Goals

A. Understand the specific site conditions that will have an environmental impact on the design. Evaluate micro-climates, sun and wind patterns, and existing soil and drainage conditions.

B. Understand the specific water requirements for both establishment and for maintaining healthy growth of plants.

C. The conservation of irrigation water should demonstrate to the public the potential for all water-saving landscapes.

11.8.3 Design Considerations

A. Each system shall be properly zoned for the different water requirements of the landscape, as well as the different application rates of the equipment.

B. Irrigation peak demand shall be coordinated with water source to ensure adequate pressure and flow requirements. Maximum flow rate shall not exceed 5 feet per second.

C. Water-savings equipment (e.g., rain and wind sensors or a central control system) shall be specified to manage and monitor the irrigation system.

D. Reclaimed or recycled water shall be used wherever available.

E. Any station roofs or canopies should be viewed for their potential to collect rainfall for irrigation of planting areas.

F. System design should efficiently and uniformly distribute water at a rate equivalent to the soil's absorption rate to avoid any runoff.

G. All applicable plumbing and electrical codes shall be met.

H. System should have the ability to be controlled by a central computer either at the time of installation or at a future date with little additional expense or difficulty. The computer-controlled system should have the ability to manage and monitor all systems and to provide water audits accurately and efficiently. All controls that are in publicly accessible areas shall be encased in a vandal-resistant box secured with a lock.

I. System should have the ability to be converted to a non-potable water supply should a source be available, with little additional expense or difficulty.

J. Irrigation system shall run during the evenings or off-peak hours and be designed for a maximum of an 8-hour run time.

K. Where possible, a drip, sub-surface or micro-irrigation system shall be used. Standard pop-up irrigation shall be spaced at 80% "head-to-head" coverage and shall avoid overspray on buildings, streets, sidewalks, paving, or adjacent properties.

L. Remote-controlled valves shall be clustered around common shut-off valves (gate valve) to isolate laterals for maintenance and repair. Master valves and shut-off valves shall be used.

M. Water-conserving devices, such as check valves, moisture and rain sensors, wind and evapotranspiration sensors, and pressure regulators shall be used.

N. Approved backflow prevention devices shall be used.

O. Locations of hose bibs shall be coordinated with mechanical designers.

Appendix A
Hawaii Chapter of the
American Society of Landscape Architects
Invasive Plant Assessment

DO NOT PLANT		
1	*Acacia auriculiformis*	Darwin black wattle
2	*Acacia crassicarpa*	Northern wattle
3	*Acacia farnesiana*	Sweet acacia
4	*Acacia longifolia*	Sidney Goldern wattle
5	*Acacia mearnsii*	Australian acacia
6	*Acacia melanoxylon*	Australian blackwood
7	*Acacia nilotica*	Gum Arabic tree
8	*Acacia parramattensis*	Parrmatta green wattle
9	*Adenanthera pavonina*	Peacock tree
10	*Aeschynomene americana*	American goint vetch
11	*Ajuga reptans*	Common bugleweed
12	*Albizia chinensis*	Chinese albizia
13	*Albizia lebbeck*	Woman's-tongue tree
14	*Alocasia cucullata*	Dwarf elephant ear
15	*Angiopteris evecta*	Giant fern
16	*Antigonon leptopus*	Mexican creeper
17	*Ardisia crenata*	Coral ardisia
18	*Ardisia elliptica*	Shoebutton ardisia
19	*Asparagus setaceus*	Common asparagus fern
20	*Asystasia gangetica*	Chinese violet
21	*Bauhinia monandra*	Pink orchid tree
22	*Bischofia javanica*	Bishopwood
23	*Brachiaria mutica*	Para grass
24	*Buddleja davidii*	Orange eye butterflybush
25	*Buddleja madagascariensis*	Smokebush
26	*Caesalpinia bonduc*	Nickerbean
27	*Caesalpinia decapetala*	Cat's claw
28	*Caesalpinia major*	Yellow nicker
29	*Cardiospermum halicacabum*	Baloon vine
30	*Casuarina cunninghamiana*	Cunninghamia beefwood
31	*Cecropia peltata*	Trumpet tree
32	*Centrosema pubescens*	Centro
33	*Chrysophyllum oliviforme*	Satin leaf
34	*Cinchona pubescens*	Red cinchona

DO NOT PLANT		
35	*Cinnamomum verum*	Cinnamon tree
36	*Citharexylum spinosum*	Fiddlewood
37	*Clerodendrum buchananii*	Red clerodendrum
38	*Clerodendrum quadriloculare*	Bronze-leaved clerodendrum
39	*Clitoria ternatea*	Butterfly pea
40	*Coccinia grandis*	Ivy gourd
41	*Corymbia citriodora*	Lemon-scented gum
42	*Cotoneaster pannosus*	Silverleaf cotoneaster
43	*Cryptostegia madagascariensis*	Madagascar rubber vine
44	*Cyathea cooperi*	Australian tree fern
45	*Cyperus involucratus*	Umbrella sedge
46	*Dalbergia sissoo*	Indian rosewood
47	*Delairea odorata*	German ivy
48	*Desmanthus virgatus*	Slender mimosa
49	*Dichrostachys cinerea*	Sickle bush
50	*Dissotis rotundifolia*	Dissotis
51	*Elaeagnus umbellata*	Autumn olive
52	*Erigeron karvinskianus*	Mexican daisy
53	*Eucalyptus grandis*	Rose gum
54	*Eucalyptus paniculata*	Grey ironbark
55	*Falcataria moluccana*	Albizia
56	*Ficus rubiginosa*	Port Jackson fig
57	*Fraxinus uhdei*	Tropical ash
58	*Gazania rigens var. leucolaena*	Trailing gazania
59	*Grevillea banksii*	Red silk oak
60	*Grevillea robusta*	Silk oak
61	*Hedychium gardnerianum*	Kahili ginger
62	*Hiptage benghalensis*	Hiptage
63	*Hypericum canariense*	Canary Island St. Johnswort
64	*Hypericum perforatum*	Common St. Johnswort
65	*Indigofera suffruticosa*	Wild indigo
66	*Jasminum fluminense*	Brazilian jasmine
67	*Jatropha gossypiifolia*	Belly-ache bush
68	*Lantana camara*	Lantana wildtype
69	*Leonotis nepetifolia*	Annual lion's ear
70	*Leptospermum scoparium*	Broom teatree
71	*Lespedeza cuneata*	Chinese lespedeza
72	*Leucaena leucocephala*	Leucaena
73	*Ligustrum sinense*	Chinese privet

DO NOT PLANT		
74	*Macfadyena unguis-cati*	Cat's claw vine
75	*Macroptilium atropurpureum*	Siratro
76	*Melaleuca quinquenervia*	Paper bark tree
77	*Melastoma candidum*	Indian rhododendron
78	*Melia azedarach*	Chinaberry tree
79	*Merremia tuberosa*	Wood rose
80	*Miconia calvescens*	Miconia
81	*Mimosa diplotricha*	Giant sensitive plant
82	*Mimosa pigra*	Catclaw mimosa
83	*Miscanthus floridulus*	Giant miscanthus
84	*Montanoa hibiscifolia*	Treedaisy
85	*Morella faya*	Firetree
86	*Mucuna pruriens*	Cowitch
87	*Muntingia calabura*	Jamaica cherry
88	*Neonotonia wightii*	Perennial soybean
89	*Paederia foetida*	Maile pilau
90	*Panicum maximum*	Guinea grass
91	*Parkinsonia aculeata*	Jerusalum thorn
92	*Paspalum dilatatum*	Dallis grass
93	*Paspalum notatum*	Bahia grass
94	*Passiflora rubra*	Red passionfruit
95	*Paulownia tomentosa*	Princess tree
96	*Pennisetum purpureum*	Elephant grass
97	*Pennisetum setaceum*	Fountain grass
98	*Pentalinon luteum*	Wild allamanda
99	*Phormium tenax*	New Zealand flax
100	*Phyla nodiflora*	Matchweed
101	*Pinus radiata*	Monterey pine
102	*Piper aduncum*	Spiked pepper
103	*Pithecellobium dulce*	Madras thorn
104	*Pittosporum undulatum*	Australian cheesewood
105	*Polygonum capitatum*	Pink knotweed
106	*Prosopis juliflora*	Thorny kiawe
107	*Psidium guajava*	Common guava
108	*Psidium guineense*	Brazilian guava
109	*Pueraria phaseoloides*	Tropical kudzu
110	*Pyracantha angustifolia*	Narrowleaf firethorn
111	*Rhodomyrtus tomentosa*	Rose myrtle
112	*Rubus argutus*	Prickly Florida blackberry

DO NOT PLANT		
113	*Salvinia molesta*	Giant salvinia
114	*Schefflera actinophylla*	Octopus tree
115	*Schinus molle*	Peruvian pepper tree
116	*Schinus terebinthifolius*	Christmas berry
117	*Senecio madagascariensis*	Fireweed
118	*Senna alata*	Candle bush
119	*Sesbania punicea*	Rattlebox
120	*Solanum seaforthianum*	Brazilian nightshade
121	*Spartium junceum*	Spanish broom
122	*Spathodea campanulata*	African tulip tree
123	*Stylosanthes guianensis*	Stylo
124	*Tamarix aphylla*	Athel tamarisk
125	*Tamarix gallica*	Saltcedar
126	*Tecoma stans*	Yellow bells
127	*Tephrosia candida*	White tephrosia
128	*Tephrosia purpurea*	Pila
129	*Thunbergia grandiflora*	Blue trumpet vine
130	*Tibouchina urvilleana*	Glory bush
131	*Tillandsia usneoides*	Spanish moss
132	*Turnera ulmifolia*	Yellow alder
133	*Ulex europaeus*	Gorse
134	*Zizyphus mauritiana*	Indian jujube

CONTINUE TO PLANT WITH CAUTION		
1	*Acacia confusa*	Formosan koa
2	*Asparagus densiflorus*	Asparagus fern
3	*Axonopus compressus*	Broadleaf carpet grass
4	*Carpobrotus edulis*	Ice plant
5	*Casuarina equisetifolia*	Iron wood
6	*Cinnamomum camphora*	Camphor tree
7	*Coffea arabica*	Coffee
8	*Dieffenbachia seguine (outdoors)*	Dumbcane
9	*Duranta erecta*	Golden dew drop
10	*Epipremnum pinnatum*	Pothos
11	*Eugenia uniflora*	Surinam cherry
12	*Ficus microcarpa*	Chinese banyon
13	*Hedychium coronarium*	White ginger
14	*Heliconia psittacorum*	Parrot's beak

CONTINUE TO PLANT WITH CAUTION		
15	*Lantana montevidensis*	Trailing lantana
16	*Liriope spicata*	Creeping lilyturf
17	*Lolium multiflorum*	Annual ryegrass
18	*Lonicera japonica*	Japanese honeysuckle
19	*Paspalum conjugatum*	Hilograss
20	*Paspalum vaginatum*	Seashore paspalum
21	*Pennisetum clandestinum*	Kikuyu grass
22	*Pimenta dioica*	Allspice tree
23	*Psidium cattleianum*	Strawberry guava
24	*Ptychosperma macarthurii*	Macarthur palm
25	*Pyrostegia venusta*	Flame vine
26	*Salix babylonica*	Babylon weeping willow
27	*Sansevieria trifasciata*	Mother-in-law's tongue
28	*Senna surattensis*	Kolomona
29	*Sphagneticola trilobata*	Wedelia
30	*Stenotaphrum secundatum*	St. Augustine grass
31	*Syngonium podophyllum*	Arrowhead plant
32	*Thevetia peruviana*	Be-still tree
33	*Washingtonia filifera*	California fan palm
34	*Washingtonia robusta*	Mexican fan palm

END OF CHAPTER

Honolulu High-Capacity Transit Corridor Project

(Project)

DESIGN CRITERIA

CHAPTER 12

PASSENGER VEHICLES

May 22, 2009

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12.0 PASSENGER VEHICLES

12.1 GENERAL

12.1.1 Introduction

The purpose of this Chapter is to establish the standards and design requirements of the basic functional, operational, and physical characteristics of the high-floor light metro transit vehicle to be used for the Honolulu High-Capacity Transit Corridor Project (the Project). It is intended to provide sufficient interface information to develop passenger vehicles and other project systems design during the Preliminary Engineering phase, as well as estimates of capital, operating, and maintenance costs.

12.1.2 Reference Data

A. Definitions

1. Vehicle: The smallest passenger carrying unit or car that can operate independently.
2. Train: A set of one or more vehicles or cars coupled together and operated as a single unit, trainset, or consist.
3. System: The Honolulu Rail Transit System developed under the Honolulu High-Capacity Transit Corridor Project.

All vehicles provided for the initial and subsequent fleets shall be essentially identical and shall operate interchangeably in any train and on any part of the System.

12.2 INITIAL SYSTEM CHARACTERISTICS

The First Project segment of the System will extend from East Kapolei to the Ala Moana Shopping Center in Honolulu. General system characteristics of this initial segment are as follows:

A.	Initial system length (end to end):	20 miles (two tracks)
B.	Number of stations:	21
C.	Station platform length:	240 feet
D.	System passenger carrying capacity:	6,300 passengers per hour per direction
E.	End-to-end travel time:	43 minutes
F.	System operating hours:	4:00 a.m. to midnight 6:00 a.m. to 9:00 a.m. morning peak 3:00 p.m. to 6:00 p.m. evening peak

12.3 TRACKWORK AND ALIGNMENT CHARACTERISTICS

For alignment details, refer to Chapter 4, Track Alignment and Vehicle Clearances. For trackwork characteristics, refer to Chapter 5, Trackwork.

12.4 TRACTION ELECTRIFICATION SYSTEM CHARACTERISTICS

A. The basic third rail contact power limitations under which the passenger vehicles shall operate in revenue service are detailed in Chapter 13, Traction Electrification. All vehicle propulsion and auxiliary equipment shall be designed for operation at these voltages without damage, failure of the equipment to function, or reduction in required service life.

B. All vehicles shall provide automatic forced reduced performance further limiting the vehicle maximum line current under low voltage conditions, as further defined below.

12.5 VEHICLE GENERAL CHARACTERISTICS

12.5.1 General

A. The vehicles shall be of a high-floor light metro transit vehicle type.

B. Each vehicle shall consist of a single section riding on two trucks with a high floor to allow level boarding from high-level station platforms. Vehicles shall be of two types: end cars and middle cars. These cars shall be capable of being semi-permanently coupled into multicar consists of two or more cars to form one single operating trainset or consist with an end car at each end, not to exceed 300 feet in length between the first and last side passenger doors (i.e., all passenger doors shall open on the station platform).

C. Alternative designs may be proposed using articulated, permanently coupled vehicles that share trucks between vehicle sections.

D. With either design approach, it shall be possible to easily insert additional cars/sections into the trainset to increase capacity in the future.

E. All axles on all vehicles in the train shall be powered.

F. Passenger movement between cars in a trainset shall be via wide gangways, full-width designs being preferred so as to provide clear sightlines throughout the consist.

G. The vehicle trainsets shall be bi-directional and fully automated. End cars shall be provided with hidden hostler operating control panels to allow manual operation. For further details regarding train control, see Chapter 14, Train Control.

H. Each end car shall be equipped with energy-absorbing, fully automatic couplers, as detailed below. The end car structures shall also be capable of absorbing collision energy in the event of a major collision, as described herein.

I. Each car shall be equipped with four third-rail collector assemblies with breakaway shoes, one to be mounted on each side of each truck. Each collector assembly shall be equipped with an integral mounted, fast-acting ribbon fuse.

J. Four to six bi-parting, wide, power-operated passenger doors shall be provided for each car, two to three per side directly opposite the doors on the other side. Each end car shall also have at least one manually operated crew access door with suitable recessed steps and grab handles to allow entrance into the vehicle from ground level. Additional specific passenger door requirements are defined below.

K. Braking shall be provided by a combination of electrically controlled friction brakes, dynamic braking, and regenerative braking.

L. Propulsion shall be via microprocessor-controlled AC traction motors or equivalent.

M. Americans with Disabilities Act (ADA) compliance is required for all aspects of the vehicle design and construction.

N. The fire safety design and construction of the vehicle shall be in compliance with all applicable vehicle-related requirements of the latest issue of National Fire Protection Association (NFPA) 130.

O. Vehicles shall provide the maximum number of seats available to passengers, including the provision of tip-up seats in standee/multi-purpose areas. A minimum of 25 percent of the design load (AW2) passengers shall be provided with seats (fixed plus tip-ups).

P. All passenger seating shall be suitable for use by a U.S. 5th-percentile female and 95th-percentile male. In particular, the knees of a 95th percentile male shall not be in contact with the seat back of the seat in front of him when seated. To ensure this, the distance from the buttocks of the seated passenger to the seat back in front of him shall not be less than 28 inches.

Q. Each vehicle shall provide accommodations for baggage and at least two wheelchairs, four surfboards, and three bicycles. This may be accomplished by providing multi-purpose areas, and all requirements need not be met simultaneously.

R. All vehicles shall be air-conditioned. The heating, ventilation, air conditioning (HVAC) system shall be high-performance/energy-efficient and suitable for use in the environmental conditions of the City and County of Honolulu (the City). Additional specific HVAC system-performance requirements are defined below.

S. Communication systems on board vehicles are defined herein.

T. The vehicle design shall include and use in its construction as much “service-proven” and “off-the-shelf” technology as possible.

U. The design service life of the vehicle shall be no less than 30 years.

V. The vehicle exterior and interior shall be of a modern and attractive design in harmony with the environment of O‘ahu.

12.5.2 General Operating Characteristics

A. The vehicle shall be capable of full-performance multiple-vehicle operation in consists of up to the maximum number of vehicles that will be able to load/unload with all doors on the station platform during normal daily operations.

B. Under emergency conditions, a consist shall be able to couple to another similar-length consist that may be inoperable and without power or only partially operational, and shall be capable of operating in a rescue mode under reduced performance at speeds of up to 30 miles per hour (mph).

12.5.3 Critical Vehicle Dimensions

The following are the limiting major dimensions for the Project's light metro transit vehicle:

		Nominal
A.	Length of vehicle	60 feet
B.	Width of vehicle	10 feet
C.	Height of vehicle	Up to 13.3 feet
D.	Height of floor	3.77 feet above top of rail
E.	Passenger side doors, clear open width	48.0 inches minimum, 66.0 inches maximum
F.	Under-floor clearance	7.87 inches minimum (vehicle edge) 5.12 inches minimum (vehicle center) above top of rail
G.	Interior height: center-line floor to ceiling	80.0 inches minimum
H.	Truck/vehicle clearance (excepting wheels), normal operating conditions of maximum wheel wear and primary suspension settlement	2 inches minimum above top of rail
I.	Truck/vehicle clearance (except wheels), worst-case conditions of wheel wear and suspension failure	1.25 inches minimum above top of rail
J.	Track gauge	4 feet, 8.5 inches (56.5 inches)
K.	Wheel gauge	56.00 inches
L.	Wheel profile	Draft design as per Figure 12-1
M.	Maximum vehicle roll angle	4.0 degrees
N.	Dynamic swept envelope	As per Section 12.6

12.5.4 Ergonomic/Universal/Accessibility Design

A. The vehicles, their systems, and sub-systems shall be designed so as to be easy to use, simple, efficient, reliable, accessible, and safe for the widest possible range of passengers and agency personnel.

B. Establishing a good man-machine interface through ergonomic design is well established and refined, especially in the military environment, where the standard MIL-STD-1472F – Department of Defense Design Criteria Standard − Human Engineering, establishes detailed and easily understandable criteria. These design criteria shall be the basis for the absolute minimum ergonomic requirements for the vehicle design.

C. For ergonomic design purposes, the vehicle shall be able to accommodate as a minimum the range of passengers and agency personnel ranging from the U.S. 5th-percentile female to the 95th-percentile male. Current U.S. anthropometric details to be used are in Architectural Graphic Standards, 10th edition – Section 1: Human Dimensions. Where these details are insufficiently comprehensive, MIL-HDBK-759C – Human Engineering Design Guidelines, Section 5.6, Tables 16a though 16f, General Forces shall be used.

D. Corridors and aisles shall have a height of at least 80 inches. The main aisle width shall be at least 34 inches to permit access by a wheelchair from all passenger doors. All standing passengers shall have access to vertical stanchions or handholds. The window area shall be maximized to emphasize a feeling of openness.

E. The interior shall have no sharp corners or inaccessible areas at floor level and shall be easy to clean and maintain. Handholds, lights, air vents, armrests, and other interior fittings shall appear to be integral with the vehicle interior. There shall be no sharp, abrasive edges, corners, or surfaces, and no hazardous protuberances.

F. Interior panel material shall permit easy removal of paint, greasy fingerprints, and ink from felt tip pens, etc. Materials shall be strong enough to resist everyday use and shall be resistant to scratches and markings. Use of visible fasteners shall be minimal, and any interior mullion trim, moldings, and trim strips shall match the adjacent panels and walls.

G. Seats shall be easily maintained and resistant to vandalism.

H. Full accessibility for all passengers shall be provided at all doors for the elderly or persons with disabilities, as well as those using assistive devices such as wheelchairs in accordance with the ADA requirements of 49 CFR 38 − Transportation for Individuals with Disabilities, Subpart D, Light Rail Vehicles and Systems, Sections 38.71 to 38.87. These requirements shall include the following:

1. The clear bodyside passenger door opening shall be 48.0 inches minimum. Wider clear door openings are preferred.

2. The clear height of the bodyside passenger door opening shall be a minimum of 79.9 inches.

3. Doors shall not protrude more than 3.0 inches maximum from the vehicle side at the threshold level during any portion of the open or close cycle and shall not contact the platform at any time.

4. The vehicle suspension system shall automatically maintain the level of the vehicle floor such that the door threshold shall be within ±0.250 inch of the station platform height.

5. The vehicle step distance from the edge of the vehicle door threshold to the station platform shall not exceed 3 inches.

I. The vehicle floor shall be covered with slip-resistant rubber flooring material and shall comply with all applicable ADA requirements for visibility and friction coefficients. Colors for the floor covering and step nosing shall complement the vehicle's overall interior design.

12.5.5 Aesthetic Design

The vehicle manufacturer shall use professional industrial design services to create a fun, easy to use, and attractive overall vehicle aesthetic interior and exterior design that respect the people who use it and the people it passes by. The vehicle design shall be visually distinctive and appealing to riders, reflecting a modern, forward-thinking image.

12.5.6 Passenger Doors

A. All passenger doors shall be fully glazed and of the two-panel, sliding-plug type.

B. All door panels shall be flush with the car body when closed. Closed door panels shall seal to prevent the ingress of water during the car wash operation, or proceeding at maximum speed in revenue service under worst-case climatic conditions.

C. The door control system shall be trainlined so that the train control system can either operate automatically or authorized personnel can manually open, close, or enable all left side and all right side passenger doors in the consist using controls on the hostler operating control panel. All door control circuits for one side of the car shall be separate and distinct from those for the other side of the car.

D. All passenger-door controls and push-button illumination circuits shall be electrically interlocked with the no-motion circuit, which shall permit the doors to be electrically opened only when vehicle no-motion is detected.

E. All vehicle doors shall have obstruction sensing capability that shall momentarily interrupt door closure whenever an obstruction is detected to allow the obstruction to be withdrawn. Doors shall not recycle, and an opposing force of 50 pounds shall be applied to resist forced reopening. After door panels have traveled more than half the closing distance, they shall be mechanically inhibited from forced reopening to more than half the panel width.

F. Doors shall be automatically mechanically locked when fully closed. All vehicle doors shall have an emergency release mechanism on both the interior and exterior of the vehicle to unlock and open the door panels manually without vehicle power and without the use of a key or similar device.

12.5.7 Trucks

12.5.7.1 Derailment Mitigation

The vehicle truck design shall provide a means of mechanically ensuring the vehicle remains on the guideway in case of derailment by entrapping the rail between the back of the wheel set and a major item of truck-mounted equipment, such as traction motor or gearbox.

12.5.7.2 Wheel Dimensions

Vehicle wheel diameters shall be between 28 inches to 34 inches in diameter. The resiliently mounted wheels shall be the same diameter on all axles of the vehicle, and the tires shall be fully interchangeable.

12.5.7.3 Truck Dimensions

The vehicle truck wheelbase shall be within the range of 5.9 feet to 7.22 feet.

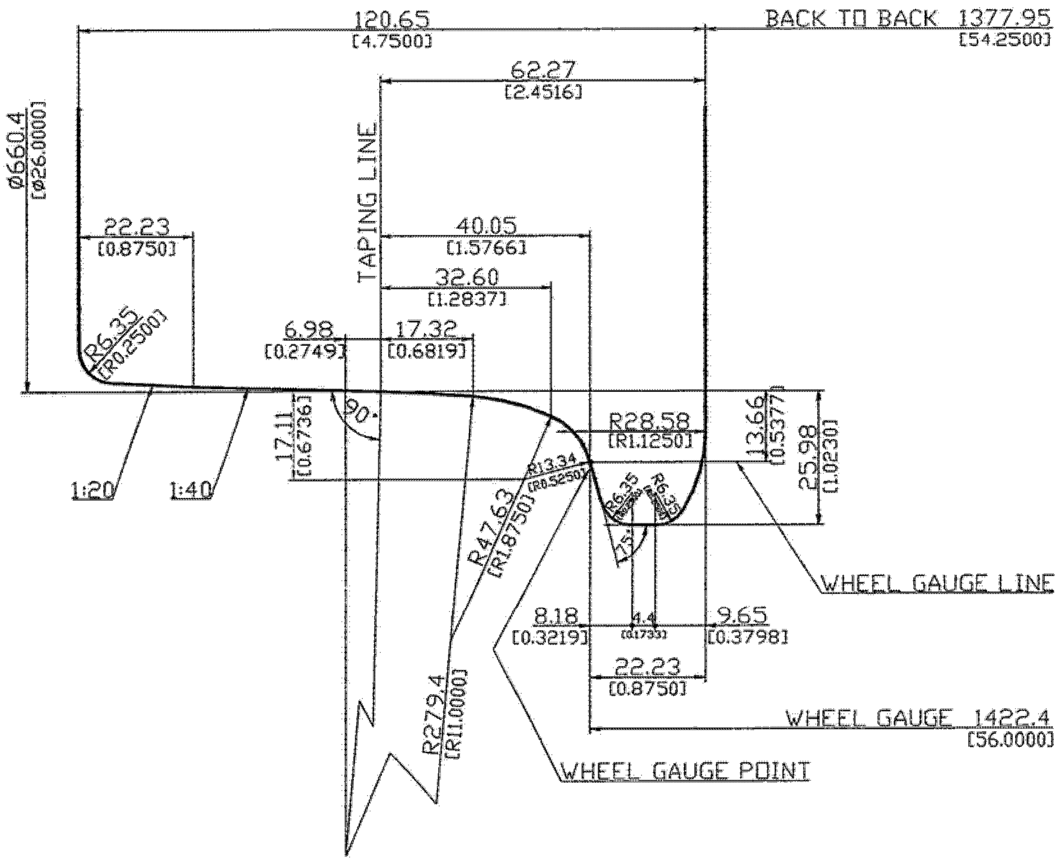
12.5.7.4 Truck Centers

Truck centers shall be between 31.17 feet and 39.37 feet.

12.5.7.5 Wheel Profile

The vehicle wheel profile shall use the standard Association of American Railroads (AAR) AAR-1B wheel profile with slight wheel width modifications, be suitable for satisfactory operation on the specified 115RE rail, and similar to the wheel profile draft design provided in Figure 12-1 below (which shall be finalized by the vehicle manufacturer).

Figure 12-1: Wheel Profile Draft Design



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12.5.8 Carbodies

12.5.8.1 Anticlimbers

Anticlimbers shall be provided on all end cars.

12.5.8.2 Controlled Collapse Vehicle Ends

A. The leading end of all end cars shall collapse in a controlled manner to absorb excess collision energy not absorbed by the autocouplers.

B. This end shall be designed to absorb at least 285,000 ft-lb of energy by means of a controlled collapse mechanism in a distance of between 20 to 28 inches.

12.5.9 Couplers

A. Couplers shall be provided on both ends of each vehicle. A positive lock shall ensure that the coupler, once engaged, cannot release without prior release of this lock.

B. The leading end of end cars shall be provided with energy-absorbing, fully automatic couplers to be identified as Type A couplers. All required electrical connections between vehicles shall be accomplished automatically during mechanical coupling and shall be disconnected automatically during mechanical uncoupling. Upon uncoupling, all required electrical contacts shall be protected by automatically deployed weather- and moisture-resistant covers.

C. Middle cars and the ends of end cars connecting with middle cars shall be provided with simple mechanical couplers, to be identified as Type B couplers, to allow semi-permanent joining of vehicles. Electrical and other connections shall be made by plug-and-socket-type jumper cables or alternative agency-approved methods.

12.5.10 Vehicle Communications

A. Each vehicle shall be provided with the following on-board communications subsystems:

1. Train-to-Wayside Radio System(s)
2. Automatic Vehicle Location/Vehicle Management System
3. Exterior forward-facing and platform monitoring video cameras/recorder
4. Wireless LAN System(s) for downloading/uploading data at maintenance facility
5. Passenger-to-Operations Control Center (OCC) Full Duplex Audio/Real-time Video Communication System
6. Interior passenger area monitoring video cameras/recorder
7. Public Address (PA) System (interior, exterior)
8. Interior Variable Message Passenger Information Displays

9. Auto-Announcer

10. Exterior Destination Displays

11. On-demand, real-time streaming of video images from the vehicles to the OCC

12. Smoke detectors with discrete alarm to OCC

B. All display and PA system controls and messages shall be trainlined to all vehicles in the train.

C. A Maintenance and Diagnostic System (MDS) shall be provided on each vehicle to provide information regarding malfunctions of vehicle systems and equipment. Each malfunction shall be uniquely indicated on an on-board status panel readily accessible to maintenance personnel. Each indicator shall continue to display the specific malfunction until it is reset.

D. An event recorder or equivalent shall be provided to record train running status and dynamic information. This record shall be physically protected against impact, with battery back-up and a locked, extractable memory storage device.

E. An on-board Automatic Passenger Counting (APC) system shall be provided.

F. Provisions shall be made for the future installation of a multi-media display and advertising system, such as AGATE e-Media or similar.

G. All data communications between vehicles and the OCC subsystems shall use an agency-approved, non-proprietary, open published communications protocol. For further details regarding communications, see Chapter 15, Communications and Control.

12.6 VEHICLE DYNAMIC SWEPT ENVELOPES

A. A nominal vehicle swept envelope has been developed that incorporates the critical dimensions and characteristics of a 60-foot-long by 10-foot-wide high floor, light metro transit vehicle.

B. The resulting swept envelope has been calculated on both tangent, level track and on a variety of curves with various super-elevations. The worst-case swept point out of all these calculations is then identified and included in the swept envelope tables presented in this section.

C. The vehicle dynamic swept envelope shall not exceed the worst-case limits identified in the following diagrams and tables. These calculated values are subject to revision as the vehicle design/procurement process further refines the vehicle dimensional limitations.

12.6.1 Vehicle Static and Dynamic Envelope on Level, Tangent Track

The determination of the Vehicle Dynamic Envelope begins with a cross-sectional outline of the vehicle standing (static) on level, tangent track, such as at a station platform. The dynamic outline of the vehicle is then developed by considering the carbody movements that can occur when the vehicle is moving (dynamic) on level, tangent track. These dynamic (sway) movements come from the truck suspension elements, wheel and rail wear, and tolerances in vehicle and track construction. The worst-case, not to exceed, dynamic body movements are shown in Table 12-1.

Figure 12-2.Simplified Clearance Diagram

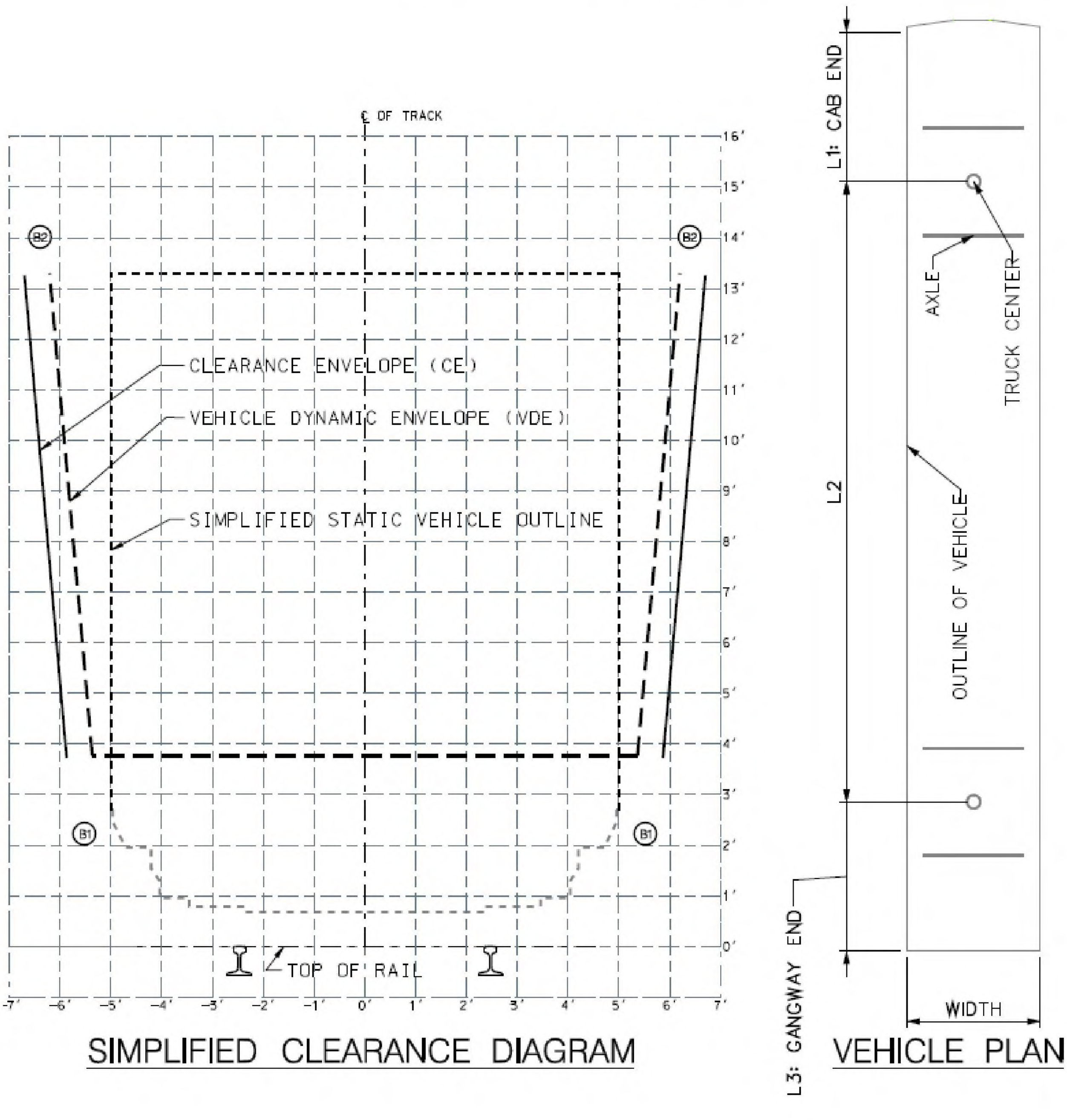


Table 12-1: Vehicle Dynamic Envelope on Level, Tangent Track

All measurements in inches from the track centerline

Dynamic Envelope
HHCTC

Superelevation		0 inches		0.5 inches		1.0 inches		1.5 inches		2.0 inches		2.5 inches	
Radius (ft)	Radius(mm)	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In
250	76200	-87.9	83.6	-86.5	84.0	-85.1	85.4	-83.7	86.8	-82.2	88.2	-80.8	89.6
300	91440	-85.7	81.2	-84.3	82.6	-82.9	84.0	-81.4	85.4	-80.0	86.8	-78.5	88.2
400	121920	-82.9	79.5	-81.5	81.0	-80.1	82.4	-78.6	83.8	-77.2	85.1	-75.7	86.5
500	152400	-81.2	78.5	-79.8	79.9	-78.4	81.3	-76.9	82.7	-75.5	84.1	-74.1	85.5
550	167640	-80.6	78.2	-79.2	79.6	-77.8	81.0	-76.3	82.4	-74.9	83.8	-73.5	85.1
600	182880	-80.1	77.9	-78.7	79.3	-77.2	80.7	-75.8	82.1	-74.4	83.5	-72.9	84.8
700	213360	-79.3	77.4	-77.9	78.8	-76.4	80.2	-75.0	81.6	-73.6	83.0	-72.1	84.4
800	243840	-78.7	77.0	-77.3	78.4	-75.8	79.8	-74.4	81.2	-73.0	82.6	-71.5	84.0
900	274320	-78.2	76.7	-76.8	78.1	-75.4	79.5	-73.9	80.9	-72.5	82.3	-71.1	83.7
1000	304800	-77.8	76.5	-76.4	77.9	-75.0	79.3	-73.6	80.7	-72.1	82.1	-70.7	83.5
1200	365760	-77.3	76.2	-75.9	77.6	-74.4	79.0	-73.0	80.4	-71.6	81.8	-70.1	83.2
1250	381000	-77.2	76.1	-75.8	77.5	-74.3	78.9	-72.9	80.3	-71.5	81.7	-70.0	83.1
1450	441960	-76.8	75.9	-75.4	77.3	-74.0	78.7	-72.5	80.1	-71.1	81.5	-69.7	82.9
1500	457200	-76.7	75.8	-75.3	77.2	-73.9	78.6	-72.5	80.0	-71.0	81.4	-69.6	82.8
2000	609600	-76.2	75.5	-74.7	76.9	-73.3	78.3	-71.9	79.7	-70.5	81.1	-69.0	82.5
2500	762000	-75.8	75.3	-74.4	76.7	-73.0	78.1	-71.6	79.5	-70.1	80.9	-68.7	82.3
3200	975360	-75.5	75.1	-74.1	76.5	-72.7	77.9	-71.3	79.3	-69.8	80.7	-68.4	82.1
5000	1524000	-75.1	74.9	-73.7	76.3	-72.3	77.7	-70.9	79.1	-69.5	80.5	-68.0	81.9
10000	3.E+06	-74.8	74.7	-73.4	76.1	-72.0	77.5	-70.5	78.9	-69.1	80.3	-67.7	81.7
Tangent		-75.1	75.1										

Superelevation		3.0 inches		3.5 inches		4.0 inches		4.5 inches		5.0 inches		5.5 inches		6.0 inches	
Radius (ft)	Radius(mm)	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In
250	76200	-79.3	90.9	-77.9	92.3	-76.4	93.7	-74.9	95.0	-73.5	96.4	-72.0	97.7	-70.5	99.1
300	91440	-77.1	89.6	-75.6	91.0	-74.2	92.3	-72.7	93.7	-71.2	95.0	-69.8	96.4	-68.3	97.7
400	121920	-74.3	87.9	-72.8	89.3	-71.4	90.6	-69.9	93.0	-68.4	93.4	-67.0	94.7	-65.5	96.0
500	152400	-72.6	86.9	-71.2	88.3	-69.7	89.6	-68.2	91.0	-66.8	92.3	-65.3	93.7	-63.8	95.0
550	167640	-72.0	86.5	-70.6	87.9	-69.1	89.3	-67.6	90.6	-66.2	92.0	-64.7	93.3	-63.2	94.7
600	182880	-71.5	86.2	-70.0	87.6	-68.6	89.0	-67.1	90.3	-65.6	91.7	-64.2	93.0	-62.7	94.4
700	213360	-70.7	85.7	-69.2	87.1	-67.8	88.5	-66.3	89.8	-64.8	91.2	-63.4	92.5	-61.9	93.9
800	243840	-70.1	85.4	-68.6	86.7	-67.2	88.1	-65.7	89.5	-64.2	90.8	-62.8	92.2	-61.3	93.5
900	274320	-69.6	85.1	-68.2	86.5	-66.7	87.8	-65.3	89.2	-63.8	90.6	-62.3	91.9	-60.8	93.2
1000	304800	-69.3	84.9	-67.8	86.2	-66.3	87.6	-64.9	89.0	-63.4	90.3	-61.9	91.7	-60.5	93.0
1200	365760	-68.7	84.5	-67.2	85.9	-65.8	87.3	-64.3	88.6	-62.9	90.0	-61.4	91.3	-59.9	92.7
1250	381000	-68.6	84.5	-67.1	85.8	-65.7	87.2	-64.2	88.6	-62.7	89.9	-61.3	91.3	-59.8	92.6
1450	441960	-68.2	84.2	-66.8	85.6	-65.3	87.0	-63.8	88.3	-62.4	89.7	-60.9	91.0	-59.4	92.4
1500	457200	-68.1	84.2	-66.7	85.6	-65.2	86.9	-63.8	88.3	-62.3	89.7	-60.8	91.0	-59.3	92.3
2000	609600	-67.6	83.9	-66.1	85.2	-64.7	86.6	-63.2	88.0	-61.7	89.3	-60.3	90.7	-58.8	92.0
2500	762000	-67.2	83.7	-65.8	85.0	-64.3	86.4	-62.9	87.8	-61.4	89.1	-59.9	90.5	-58.4	91.8
3200	975360	-66.9	83.5	-65.5	84.9	-64.0	86.2	-62.6	87.6	-61.1	88.9	-59.6	90.3	-58.2	91.6
5000	1524000	-66.6	83.2	-65.1	84.6	-63.7	86.0	-62.2	87.4	-60.7	88.7	-59.3	90.1	-57.8	91.4
10000	3.E+06	-66.2	83.0	-64.8	84.4	-63.3	85.8	-61.9	87.2	-60.4	88.5	-58.9	89.9	-57.4	91.2

Basic Assumptions / Criteria

1. Cross level variaton: 1.0 inch.
2. Maximum vehicle roll angle: 4 degrees.
3. Vehicles do not have cameras or mirrors.

4. Envelope assumes the following: a Light Metro Vehicle with a 10 ft. wide, 60 ft. long body centered over trucks (axle spacing of 6.89 ft.) spaced at 36.09 ft. centers. The floor height is 3.77 ft above top of rail and the body is a maximum of 13.3 ft. above top of rail.

5. Calculations include wheel and track tolerances including wheel wear, track wear, rail gauge tolerance, wheel gauge tolerance, nominal sideplay and lateral suspension motion totalling 69 mm.
6. Resulting values are worst case calculated values.

12.6.2 Vehicle Dynamic Envelope on Curved Track

A. In addition to the dynamic car body movements on level, tangent track described above, car body overhang on horizontal track curvature also increases the lateral displacement of dynamic outline relative to the track centerline depending on the radius of the curve, the cross-level variation, the degree of track superelevation, the wheel and track tolerances, and the suspension motion.

B. In determining the superelevation effects, the shape of the vehicle dynamic outline has not been altered and the effects have been limited to the vehicle lean introduced by the specified difference in the top of rail (TOR) elevation between the two rails of the track under consideration (cross-level variation).

C. The resulting worst-case dynamic outswing and inswing values are presented in Tables 12-2 and 12-3, respectively. These tables shall be used as the Vehicle Dynamic Envelope (VDE) in establishing the Track Clearance Envelope (TCE).

Table 12-2: Vehicle Outswing Values

All measurements in inches from the track centerline

Dynamic Envelope
HHCTC

Table, Outswing Values														
Superelevation, Inches		0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
Radius (ft)	Radius(mm)	Out	Out	Out	Out	Out	Out	Out	Out	Out	Out	Out	Out	Out
250	76200	-87.9	-86.5	-85.1	-83.7	-82.2	-80.8	-79.3	-77.9	-76.4	-74.9	-73.5	-72.0	-70.5
300	91440	-85.7	-84.3	-82.9	-81.4	-80.0	-78.5	-77.1	-75.6	-74.2	-72.7	-71.2	-69.8	-68.3
400	121920	-82.9	-81.5	-80.1	-78.6	-77.2	-75.7	-74.3	-72.8	-71.4	-69.9	-68.4	-67.0	-65.5
500	152400	-81.2	-79.8	-78.4	-76.9	-75.5	-74.1	-72.6	-71.2	-69.7	-68.2	-66.8	-65.3	-63.8
550	167640	-80.6	-79.2	-77.8	-76.3	-74.9	-73.5	-72.0	-70.6	-69.1	-67.6	-66.2	-64.7	-63.2
600	182880	-80.1	-78.7	-77.2	-75.8	-74.4	-72.9	-71.5	-70.0	-68.6	-67.1	-65.6	-64.2	-62.7
700	213360	-79.3	-77.9	-76.4	-75.0	-73.6	-72.1	-70.7	-69.2	-67.8	-66.3	-64.8	-63.4	-61.9
800	243840	-78.7	-77.3	-75.8	-74.4	-73.0	-71.5	-70.1	-68.6	-67.2	-65.7	-64.2	-62.8	-61.3
900	274320	-78.2	-76.8	-75.4	-73.9	-72.5	-71.1	-69.6	-68.2	-66.7	-65.3	-63.8	-62.3	-60.8
1000	304800	-77.8	-76.4	-75.0	-73.6	-72.1	-70.7	-69.3	-67.8	-66.3	-64.9	-63.4	-61.9	-60.5
1200	365760	-77.3	-75.9	-74.4	-73.0	-71.6	-70.1	-68.7	-67.2	-65.8	-64.3	-62.9	-61.4	-59.9
1250	381000	-77.2	-75.8	-74.3	-72.9	-71.5	-70.0	-68.6	-67.1	-65.7	-64.2	-62.7	-61.3	-59.8
1450	441960	-76.8	-75.4	-74.0	-72.5	-71.1	-69.7	-68.2	-66.8	-65.3	-63.8	-62.4	-60.9	-59.4
1500	457200	-76.7	-75.3	-73.9	-72.5	-71.0	-69.6	-68.1	-66.7	-65.2	-63.8	-62.3	-60.8	-59.3
2000	609600	-76.2	-74.7	-73.3	-71.9	-70.5	-69.0	-67.6	-66.1	-64.7	-63.2	-61.7	-60.3	-58.8
2500	762000	-75.8	-74.4	-73.0	-71.6	-70.1	-68.7	-67.2	-65.8	-64.3	-62.9	-61.4	-59.9	-58.4
3200	975360	-75.5	-74.1	-72.7	-71.3	-69.8	-68.4	-66.9	-65.5	-64.0	-62.6	-61.1	-59.6	-58.2
5000	1524000	-75.1	-73.7	-72.3	-70.9	-69.5	-68.0	-66.6	-65.1	-63.7	-62.2	-60.7	-59.3	-57.8
10000	3048000	-74.8	-73.4	-72.0	-70.5	-69.1	-67.7	-66.2	-64.8	-63.3	-61.9	-60.4	-58.9	-57.4
Tangent		-75.1												

Basic Assumptions / Criteria

1. Cross level variaton: 1.0 inch.
2. Maximum vehicle roll angle: 4 degrees.
3. Vehicles do not have cameras or mirrors.

4. Envelope assumes the following: a Light Metro Vehicle with a 10 ft. wide, 60 ft. long body centered over trucks (axle spacing of 6.89 ft.) spaced at 36.09 ft. centers. The floor height is 3.77 ft above top of rail and the body is a maximum of 13.3 ft. above top of rail.

5. Calculations include wheel and track tolerances including wheel wear, track wear, rail gauge tolerance, wheel gauge tolerance, nominal sideplay and lateral suspension motion totalling 69 mm.
6. Resulting values are worst case calculated values.

Table 12-3: Vehicle Inswing Values

All measurements in inches from the track centerline — Dynamic Envelope HHCTC

Table, Inswing Values														
Superelevation, Inches		0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
Radius (ft)	Radius(mm)	In	In	In	In	In	In	In	In	In	In	In	In	In
250	76200	82.6	84.0	85.4	86.8	88.2	89.6	90.9	92.3	93.7	95.0	96.4	97.7	99.1
300	91440	81.2	82.6	84.0	85.4	86.8	88.2	89.6	91.0	92.3	93.7	95.0	96.4	97.7
400	121920	79.5	81.0	82.4	83.8	85.1	86.5	87.9	89.3	90.6	92.0	93.4	94.7	96.0
500	152400	78.5	79.9	81.3	82.7	84.1	85.5	86.9	88.3	89.6	91.0	92.3	93.7	95.0
550	167640	78.2	79.6	81.0	82.4	83.8	85.1	86.5	87.9	89.3	90.6	92.0	93.3	94.7
600	182880	77.9	79.3	80.7	82.1	83.5	84.8	86.2	87.6	89.0	90.3	91.7	93.0	94.4
700	213360	77.4	78.8	80.2	81.6	83.0	84.4	85.7	87.1	88.5	89.8	91.2	92.5	93.9
800	243840	77.0	78.4	79.8	81.2	82.6	84.0	85.4	86.7	88.1	89.5	90.8	92.2	93.5
900	274320	76.7	78.1	79.5	80.9	82.3	83.7	85.1	86.5	87.8	89.2	90.6	91.9	93.2
1000	304800	76.5	77.9	79.3	80.7	82.1	83.5	84.9	86.2	87.6	89.0	90.3	91.7	93.0
1200	365760	76.2	77.6	79.0	80.4	81.8	83.2	84.5	85.9	87.3	88.6	90.0	91.3	92.7
1250	381000	76.1	77.5	78.9	80.3	81.7	83.1	84.5	85.8	87.2	88.6	89.9	91.3	92.6
1450	441960	75.9	77.3	78.7	80.1	81.5	82.9	84.2	85.6	87.0	88.3	89.7	91.0	92.4
1500	457200	75.8	77.2	78.6	80.0	81.4	82.8	84.2	85.6	86.9	88.3	89.7	91.0	92.3
2000	609600	75.5	76.9	78.3	79.7	81.1	82.5	83.9	85.2	86.6	88.0	89.3	90.7	92.0
2500	762000	75.3	76.7	78.1	79.5	80.9	82.3	83.7	85.0	86.4	87.8	89.1	90.5	91.8
3200	975360	75.1	76.5	77.9	79.3	80.7	82.1	83.5	84.9	86.2	87.6	88.9	90.3	91.6
5000	1524000	74.9	76.3	77.7	79.1	80.5	81.9	83.2	84.6	86.0	87.4	88.7	90.1	91.4
10000	3048000	74.7	76.1	77.5	78.9	80.3	81.7	83.0	84.4	85.8	87.2	88.5	89.9	91.2
Tangent		75.1												

Basic Assumptions / Criteria

1. Cross level variaton: 1.0 inch.
2. Maximum vehicle roll angle: 4 degrees.
3. Vehicles do not have cameras or mirrors.

4. Envelope assumes the following: a Light Metro Vehicle with a 10 ft. wide, 60 ft. long body centered over trucks (axle spacing of 6.89 ft.) spaced at 36.09 ft. centers. The floor height is 3.77 ft above top of rail and the body is a maximum of 13.3 ft. above top of rail.

5. Calculations include wheel and track tolerances including wheel wear, track wear, rail gauge tolerance, wheel gauge tolerance, nominal sideplay and lateral suspension motion totalling 69 mm.
6. Resulting values are worst case calculated values.

12.7 VEHICLE WEIGHT AND DESIGN LOADING

A. The maximum assigned weight (AW) of a vehicle shall be no greater than those shown below in Table 12-4, suitably adjusted for the contracted vehicle configuration. This table is based upon a nominal vehicle design, 60 feet long by 10 feet wide, with 50 seated passengers, 140 standees at design load, and a standard average passenger weight of 154 pounds (lbs).

1. Equipment installation shall be arranged so that its weight is evenly distributed to provide the lowest possible center of gravity to limit the tendency of the vehicle to overturn, maximize adhesion, and minimize axle loads.

Table 12-4: Vehicle Weights for Design Purposes

Loading Condition		Maximum Weight
AW0 (Ready to run)	Maximum empty vehicle operating weight	72,018 lbs.
AW1 (Seated load)	AW0 weight plus seated load of 50 passengers	79,718 lbs.
AW2 (Design load)	AW1 load plus 140 standees at 2.7 feet 2 of suitable standing space per standee [4 / m²]	101,278 lbs.
AW3 (Crush load)	AW1 load plus 210 standees at 1.8 feet 2 of suitable standing space per standee [6 / m²]	112,058 lbs.
AW4 (Structural design)	AW1 load plus 280 standees at 1.35 feet 2 of suitable standing space per standee [8 / m²]	122,838 lbs.

12.8 VEHICLE PERFORMANCE

The propulsion and braking systems shall be rated to provide safe and satisfactory operation on the System under the specified loads and anticipated environmental conditions identified herein, up to the maximum specified speed, with acceleration, deceleration, and jerk rates within acceptable passenger comfort limits.

12.8.1 Supply Voltage

All vehicle equipment shall be designed to operate satisfactorily over the power system supply range identified above.

12.8.2 Operation under Reduced Supply Voltage

To optimize the power supply system performance, forced reduced performance shall be provided under low voltage conditions. If the line voltage falls below 625 Vdc, the propulsion current limit shall be lowered progressively at a rate of 0.5 percent per volt. The control algorithm used shall provide dynamic stability of the current limiting process without oscillations or whipsaws.

12.8.3 Maximum Line Current

The maximum line draw per vehicle shall not exceed 1,350 amperes (propulsion plus auxiliaries).

12.8.4 Acceleration

A. A maximum acceleration rate of 3.00 miles per hour per second (mphps), ± 5 percent, with vehicle loadings of AW0 through AW2 and nominal line voltage, shall be available from 0 to 20 mph.

B. Acceleration rates may decrease linearly for AW2 through AW4 loadings. At line voltages below 750 Vdc, the speed to which the initial acceleration rate is held shall decrease proportionally to the third rail voltage.

C. The maximum variation between vehicles in acceleration from the nominal rate due to propulsion control shall not exceed 0.20 mphps.

12.8.5 Service Braking

A. The average deceleration rate for full service braking shall be 2.2 mphps for speeds between 55 mph and 45 mph, and 3.00 mphps ±5 percent from 45 mph to a complete stop.

B. Regenerative/dynamic braking shall contribute to the braking effort as long as possible (less than or equal to 6 mph before dynamic brake drop out).

12.8.6 Emergency Braking

For up to AW3 vehicle loadings, the average emergency deceleration rate from 55 mph to 30 mph shall be at least 3.0 mphps. From 30 mph to a full stop, the average deceleration rate shall be at least 3.25 mphps.

12.8.7 Parking Brake

A parking brake system capable of holding an AW4 loaded vehicle on a 7 percent grade for an indefinite period shall be provided.

12.8.8 Operating Speed

The maximum normal operating speed shall be 65 mph.

12.8.9 Duty Cycle

The propulsion and braking systems shall be capable of operating continuously without exceeding the continuous rating of any vehicle equipment at AW2 loading, operating in a single vehicle consist at 750 Vdc on a duty cycle comprised of full power acceleration and braking to maintain the maximum allowable track speeds between stations. Each duty cycle shall assume between 5 and 20 seconds dwell time at each station stop and layovers of between 2 and 11 minutes at the ends of the line.

12.8.10 Annual Average Mileage

The vehicle shall be designed based upon an estimated annual mileage of 45,000 miles per vehicle.

12.9 PASSENGER COMFORT

This section defines the requirements for passenger comfort on the vehicle, including HVAC, noise, ride quality, lighting, and interior design.

12.9.1 Heating Ventilation and Air Conditioning

12.9.1.1 General

A. The HVAC system design shall make every effort to reduce the requirement for air conditioning capacity through use of vehicle passive and active measures that reduce solar and radiated heat load while minimizing cool air loss. Capacity and initial functionality of the HVAC system shall be proven by full vehicle climate chamber qualification testing.

B. The HVAC system shall meet the following performance requirements:

1. Air Conditioning. Each vehicle shall have an independent air-conditioning system.

2. Ventilation and Air Circulation. All of the ventilated air shall be introduced through the air-conditioning equipment and shall not include air introduced when the doors are open. There shall be no passenger-openable windows.

3. Heating. The total heating system shall have the capacity equal to the maximum calculated heating requirement for the vehicle. No floor level or underseat heaters shall be provided.

4. Condensation and Humidity. The HVAC system shall minimize condensation on interior surfaces, including windows. Reheat is permitted if required to limit the interior humidity.

5. Controls/Temperature Uniformity. Interior temperature shall be fully automatically controlled in cooling, ventilation, and heating modes without manual intervention.

6. Air Flow, Diffusion, and Discharge Temperature. The air distribution system shall provide sufficient diffusion at the outlet or diffuser so that air mixing will prevent direct impingement of air onto occupants.

7. Environmental Emission Standards: The air-conditioning system shall meet all international environmental emission standards and shall use environmentally friendly R-407C refrigerant or agency-approved alternative.

12.9.1.2 Temperature Control

The HVAC system controls shall maintain the vehicle interior conditions so as to remain within the comfort zone of acceptable indoor operative temperature ranges as shown in Figure 12-2.

A. The maximum allowable variations in temperature in the vehicle passenger areas shall be as follows:

1. Less than 4º F variation at any height from 6 inches to 48 inches above the floor.

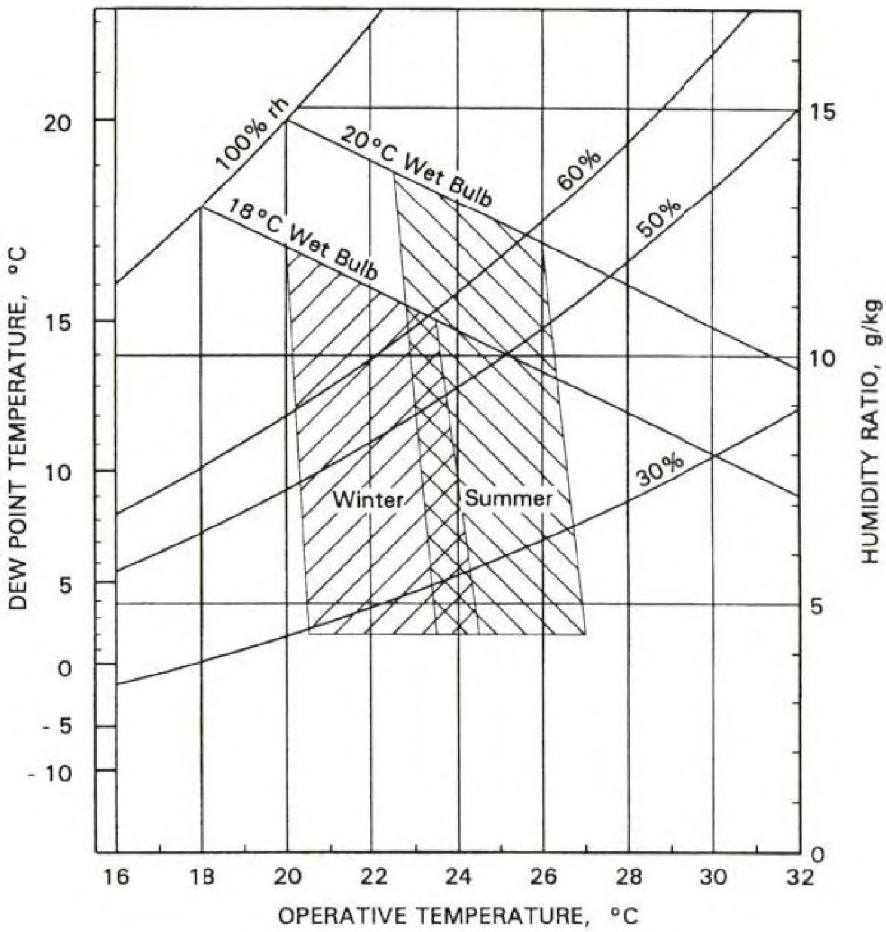
2. Average vehicle temperature shall be within 2º F of the comfort zone requirements within 2 minutes following a 30-second opening of all vehicle passenger doors on one side.

B. The maximum allowable variation in temperature in the vehicle operating cabs shall be as follows:

1. Less than 4º F variation at any height from 6 inches to 48 inches above the floor.

2. Source: ASHRAE Fundamentals Handbook – 2001, Chapter 8, Fig. 5.

Figure 12-3: ASHRAE Summer and Winter Comfort Zones



12.9.1.3 Interior Fresh Air Intake

Intake of filtered fresh air shall be provided for each vehicle, the required fresh air volume being between 1,200 ft^3/minute and 1,400 ft^3/minute regardless of vehicle position in a train or the vehicle speed and shall be adequate to maintain the positive pressurization requirements below.

12.9.1.4 Interior Air Filtration

The HVAC system filter elements shall be capable of removing fine dust and allergens to an 85 percent efficiency level per ASHRAE 52.2 – Method of Testing General Ventilation Air Cleaning Devices for Removal Efficiency by Particle Size.

12.9.1.5 Interior Positive Pressurization

The ventilation system shall maintain a vehicle internal positive static pressure at all vehicle speeds and a minimum static pressure of 0.10 inch of water when all doors and windows are closed.

12.9.1.6 Interior Maximum Air Velocity

To increase system efficiency and minimize air noise, the maximum air velocity through the HVAC ductwork shall be 1,200 ft/minute.

12.9.1.7 Design Temperatures

For the purposes of the overall HVAC system design, the following design parameters shall be used:

A. Honolulu Latitude: 21.35º, Longitude: 157.93°, Elevation: 16 feet

B. Summer Design Ambient: 89ºF DB, 76ºF WB

C. Summer Vehicle Interior: 76ºF, 50 percent RH

D. Winter Design Ambient: 61ºF DB

E. Winter Vehicle Interior: 70ºF

12.9.1.8 Cooling Loads

For the purposes of HVAC cooling system design, the following thermal load parameters shall be used in calculating HVAC system performance and sizing HVAC units:

A. Occupants: Assume vehicle AW2 loading

1. Seated passengers: 400 Btu/hr TH, 245 Btu/hr SH per passenger
2. Standees: 450 Btu/hr TH, 250 Btu/hr SH per passenger

B. Fresh Air: as required above.

C. Carbody Conduction: The Contractor shall provide “U” factors and associated surface areas for the vehicle walls, doors, ceiling, floor, window glass, and vehicle ends based on the worst-case car skin temperature and the specified interior temperature for use in the HVAC calculations.

D. Solar Gain: The attendant solar gain shall be calculated based on a Honolulu location on July 21st at 1,600 hours with the maximum possible area of vehicle window, door, and windshield glass facing into the sun.

E. External Radiated Heat Loads: Radiated heat loads generated by roof-mounted equipment and underfloor-mounted equipment, including the effect of any skirts, shall be provided. Radiated heat generated by the guideway/roadbed shall be included in the HVAC calculations with no deduction for any shading effects arising from the passing of the vehicle (i.e., the vehicle underfloor is fully exposed to this heat source).

F. Door Opening Heat Loads: For an average duty cycle, the vehicle doors may be open up to 15 percent of the journey time. Assume a worst-case loss of interior chilled air where all doors on one side of the vehicle are opened for 20 seconds at each station stop and that 300 ft^3/min of cool air is lost per door. Cooling loss/heat gain arising from periodic door opening (convection and radiated) shall be included in the HVAC calculations. The vehicle duty cycle specified above shall be used as the basis for modeling this phenomenon.

G. Internal Heat Loads: Detailed information regarding heat generated inside the vehicle by lighting, control electronics, etc. shall be provided by the vehicle manufacturer and its suppliers for input into the HVAC calculations.

12.9.2 Noise Levels

A. Special vehicle noise-abatement measures, including resilient wheels, sound-damping liners, and bodyside skirts, shall be provided to minimize noise.

B. Noise levels shall not exceed the levels indicated below under normal operating conditions with all equipment functioning. Lower noise levels are desirable.

C. Measurement of exterior noise levels shall be made under the following conditions:

1. On level ground and in an essentially free-field environment
2. 50 feet from the centerline of the track and perpendicular to the vehicle on newly ground welded rail at a height of 5 feet and away from reflecting surfaces
3. On adjacent ground other than ballast, ties, and track.

D. Measurement of interior noise levels shall be made at designated points 3 feet from the left and right side walls and 4 feet from the floor.

12.9.2.2 Interior Noise

With all auxiliary equipment operating simultaneously under normal operating conditions, noise levels inside the vehicle shall average no more than the following levels on non-corrugated, tangent track:

A.	Vehicle stationary, empty, no auxiliary systems operating:	68 dBA
B.	Vehicle stationary, all auxiliary systems operating and all HVAC units in full cooling mode:	72 dBA
C.	Vehicle stationary, with any one system operating:	70 dBA
D.	Vehicle moving, empty, at 40 mph:	75 dBA

12.9.2.3 Exterior Noise

Average noise levels emanating from the vehicle shall not exceed the following levels on non-corrugated, tangent track with all auxiliary equipment operating simultaneously:

A.	Vehicle stationary, empty:	68 dBA
B.	Vehicle moving, empty, on horizontal tangent track at 40 mph:	75 dBA
C.	In maximum dynamic braking or maximum friction braking from 40 mph with new wheels:	75 dBA

12.9.2.4 Noise/Wheel Squeal Prevention

Special wheel profiles, wheel dampers, and/or other noise-mitigation measures shall be provided on the vehicle to ensure that wheel squeal in curves does not exceed 78 dBA. Noticeable pure tones are not permitted.

12.9.3 Ride Quality

For any single station-to-station run (not including dwells), RMS accelerations between 1 and 80 Hz shall fall below the levels outlined in Evaluation of Human Exposure to Whole-Body Vibration, ISO 2631 for one hour exposure to the Reduced Comfort Boundary.

12.9.4 Interior Lighting

Vehicle interiors shall be designed with lighting fixtures that are secure, rattle-free, and vandal-resistant. Fluorescent tubes, or other powered fixtures, shall be inaccessible to passengers. Diffusers shall be shatterproof. Illumination levels, as follows, shall be consistent and shall be measured with all light-diffusing panels in place:

A. The average intensity of the illumination within the car at an elevation of 33 to 66 inches above the floor shall be at least 30 foot-candles at rated voltage.

B. The light intensity at the floor throughout the vehicle, in the passenger aisles and gangways, shall not be less than 20 foot-candles.

C. The average light intensity at car entrances and exits inside the vehicle within 20 inches of the doors shall not be less than 20 foot-candles at the floor.

D. Emergency exit lighting shall illuminate the path from each vehicle emergency exit. Such lighting shall be at least 5 foot-candles and shall be powered from the vehicle battery for no less than one hour.

It shall be possible for only authorized personnel to turn on or off interior lights.

12.10 RELIABILITY

Provided maintenance is carried out in accordance with the vehicle manufacturer's recommendations as stated in the maintenance manuals. The reliability requirements listed in Table 12-5 shall be met.

Table 12-5: Reliability Requirements

System	Mean Distance Between Component Failure
Propulsion System	90,000 miles
Friction Braking System	90,000 miles
Passenger Doors	90,000 miles
HVAC System	180,000 miles
Couplers	180,000 miles
Trucks and Suspension	180,000 miles
TWC, AVL, VMS, and Event Recorder	180,000 miles
Video Monitoring, Communications, PA, and Passenger Information	180,000 miles
Auxiliary Power Systems	225,000 miles
Lighting (except bulbs)	450,000 miles

12.11 MAINTAINABILITY

The Mean Time to Repair (MTTR) a vehicle fault shall not average more than 1.5 hours per fault, including diagnostic time.

Table 12-6 indicates the weighted average of the MTTR values for the specified subsystem elements:

Table 12-6: Weighted Average of MTTR Values

System	Mean Time to Repair (hours)
Propulsion System	1.5
Friction Braking System	1.8
Passenger Doors	0.75
HVAC System	2.0
Video Monitoring, Communications, PA, and Passenger Information	1.0
Couplers	2.5
Trucks and Suspension	1.5
TWC, AVL, VMS, and Event Recorder	1.0
Auxiliary Power System	1.5
Lighting	0.5

END OF CHAPTER

Honolulu High-Capacity Transit Corridor Project

(Project)

DESIGN CRITERIA

CHAPTER 13

TRACTION ELECTRIFICATION

May 22, 2009

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13.0 TRACTION ELECTRIFICATION

13.1 GENERAL

13.1.1 Introduction

This chapter defines the technical requirements for design of the Traction Electrification System (TES) for the Honolulu High-Capacity Transit Corridor Project (Project).

13.1.2 Reference Data

All materials, apparatus, and equipment, installation methods, and testing shall conform to or exceed the requirements of the applicable portions of the latest edition, as administered by the City and County of Honolulu (City), of ANSI, NEMA, NEC, IEEE, UL, IBC, ICEA, EIA, and ASTM. Other local and state codes may also apply. The TES shall comply with industry standards and the most stringent of these codes.

13.2 ENVIRONMENT

A. Climatic Conditions: The TES shall be designed to operate satisfactorily and without failure in the extreme climate conditions with regards to ambient temperatures, rain, humidity, and air quality as specified in Chapter 3, Environmental Considerations. For design criteria for wind forces, refer to Chapter 9, Structural.

B. Seismic Forces: For seismic design information, refer to Chapter 9, Structural.

C. Aesthetic Mitigation Measures: In environmentally sensitive areas, architectural treatment shall be used at traction power sites as described in Chapter 3, Environmental Considerations and Chapter 10, Architecture, to provide acceptable appearance of the site from the outside.

D. Substation Noise Criteria: The noise generated by a traction power substation (TPSS) in full service at 200 percent load, including air conditioning, shall not exceed the limit for ancillary/electrical equipment noise specified in Chapter 3, Environmental Considerations. Inside the TPSS building, the noise level measured at the center of the aisle during operation at 200 percent load shall not exceed 72 decibels (dB).

13.3 SYSTEM DESCRIPTION

The overall TES for the Project will be comprised of three major subsystems, as follows:

A. Traction power facilities

B. A direct current (DC) power distribution system, including a positive side comprising positive DC feeders and contact rail and a negative side comprising negative return feeders and running rails

C. An emergency trip system

13.2.1 Traction Power Facilities

Traction power facilities will include traction power substations and gap breaker stations.

Primary power to the TES will be three-phase AC provided by the Hawaiian Electric Company (HECO) at either 12.47 kilovolts (kV) or 11.5 kV. The exact incoming voltage will be established by HECO once the TPSS locations have been finalized.

TPSS will convert the 12.47 kV or 11.5 kV, three-phase, alternating current (AC) power received from HECO to DC power for distribution to trains via a contact rail system. Rectification will be achieved by either a diode-based or thyristor-controlled 12-pulse power rectifier with one transformer-rectifier unit (TRU) per substation.

Gap-breaker stations will be used at track interlockings of the double crossover type (or two single back-to-back crossovers) for contact rail sectionalizing purposes, if there is no TPSS at such a location.

13.3.2 DC Power Distribution System

The TES will convert the medium-voltage, three-phase AC power received from the electrical utility to DC power at nominal 750-volt DC system voltage and distribute it to trains for use for propulsion and auxiliary (hotel load) purposes. The TES design shall be coordinated with all other related systems (e.g., passenger vehicles, civil works, train control, and communications) to ensure an efficient, safe, and reliable electrification system meeting the specified performance, reliability, and functional requirements.

The DC power distribution system can be divided into positive and negative sides. In the positive side, the load currents flow from the substations to the trains. The negative side provides the means for the currents to return to the substations, completing the circuit. As such, it is often referred to as negative return.

The positive side will comprise a contact rail system, and positive DC feeders connecting the contact rail system to the TPSS and gap breaker stations. The negative side will comprise running rails, track impedance bonds (if necessary, depending on the train control system), cross-bonds, and negative return feeders connecting the running rails to the TPSS.

13.3.3 Emergency Trip System

The emergency trip system will provide a means to quickly de-energize sections of the contact rail system in an emergency. The signal to de-energize the contact rail will be initiated from emergency trip stations located outside the traction power facilities. The emergency trip stations will be located per NFPA 130 requirements at passenger platforms on the premises of traction power facilities and in the yard. Emergency trip stations will be part of blue light stations, which will also provide voice communication capability with the Operations Control Center (OCC).

13.4 RELIABILITY AND OPERATIONAL FLEXIBILITY

The TES shall be designed to meet the reliability and operational flexibility requirements stated herein.

13.4.1 Independence of Utility Power Supply Circuits

Medium voltage (12.47 kV or 11.5 kV depending on location) AC power to the adjacent TPSS shall be provided by independent distribution circuits of HECO supplied from the utility's 46 kV system by different step-down transformers.

13.4.2 Sectionalizing of Mainline TES

Traction power substations for the mainline will operate on a common DC network sharing the load. However, sectionalizing capability shall be provided at all track interlocking and turnouts so that contact rail sections between interlockings can be de-energized selectively in the event of fault or for maintenance. The intent is to limit the extent of the power outage zone and make possible single tracking around a problematic track segment.

The mainline sectionalizing shall be achieved by locating either a TPSS or a gap breaker station (GBS) at all double crossover track interlockings and using four-way sectionalizing of the two-track mainline contact rail.

13.4.3 Power to Mainline Contact Rail Sections

Each contact rail section of a mainline track shall be supplied from a minimum of two DC feeder circuit breakers located preferably at different traction power facilities. Short kicker-rail sections in segmented sectionalizing gaps, as well as contact rail for sidings and pocket tracks, are exempted from the multiple feed point requirement.

Sectionalizing contact rail gaps through which trains in the normal direction of travel will be accelerating, or drawing more than 250 A/vehicle due to gradients, shall be of segmented design. A segmented sectionalizing gap shall comprise a short kicker rail section with bridgeable gaps on either side. The kicker rail shall be de-energized automatically if one of the adjoining main contact rail sections is de-energized.

13.4.4 Separation of Mainline and Yard TES

The traction power systems for the yard and mainline shall be electrically isolated under normal operating conditions. The isolation shall be both on the positive and negative sides of the DC distribution system. However, the TES design shall include provisions for supplying the yard from the mainline by bridging the positive and negative sectionalizing gaps in the event the yard's TPSS is out-of-service.

13.4.5 Sectionalizing of Yard TES

A TPSS dedicated to the yard shall be used to supply DC power to the yard's contact rail system.

The sectionalizing scheme for the yard contact rail shall be developed in such a manner that a failure of a single DC feeder circuit breaker in the yard's TPSS does not critically impact train operations within the yard.

The yard's TES design shall include provisions to individually de-energize a subsection of the contact rail supplied by a DC feeder breaker by using motorized disconnect switches.

13.4.6 Traction Power Equipment Reliability

Traction power equipment and devices shall be of field-proven design with a minimum five years successful in-service record for the same or similar model.

Electronic equipment used in traction power facilities, such as protective relays or programmable logic controllers, shall have service proven or theoretically calculated mean time between failure (MBTF) not less than 100,000 hours.

Low-voltage power for control and monitoring devices in a traction power facility shall be derived from a 125-volt DC station battery system with adequate capacity to provide a minimum eight hours of operation for all equipment in case of failure of the AC low voltage system.

Electronic equipment requiring 24-volt DC control power shall be supplied from a 24-volt DC system powered off the 125-volt DC battery via redundant 125/24 volt DC/DC converters, such that a failure of a single DC/DC converter shall not affect the 24-volt DC power supply.

13.5 TES PERFORMANCE

The configuration and parameters of the TES shall be developed based on computerized simulation analysis of the Project's train operations, taking into account the dynamic nature of the traction power loads. The analysis shall account for all elements that comprise the Project's overall operating system that affect the train voltage levels and thermal ratings of the wayside traction power equipment.

13.5.1 Contingency Operations

The TES shall be designed to support the peak-period train operations plan, in terms of the prescribed headways, consist size, and passenger loading, when operating with any one TPSS being out-of-service.

The TPSS out-of-service condition shall consist of an effectively open primary AC circuit breaker, but with the DC feeder breakers remaining closed and the DC bus staying energized.

13.5.2 Passenger Vehicle

The TES shall be designed to support train operations with a rail transit vehicle equipped with AC propulsion drive featuring the characteristics defined in Chapter 12, Passenger Vehicles.

The propulsion systems of different vehicles in a multi-unit consist shall remain independent with respect to current collection from the contact rail system and shall not be trainlined.

13.5.3 Train Operations Plan

The TES will be designed to support the following train operations plan during the peak period:

A.	Consist Size	four vehicles
B.	Headway	90 seconds
C.	Uniform Passenger Loading	AW2
D.	Typical Station Dwell Time	20 seconds
E.	Peak Period Duration	two hours

13.5.4 DC Voltage Criteria

The TES key DC voltage levels and the manner of their determination shall be as specified below. All quoted DC voltages refer to the average voltage over an AC cycle length following rectification.

A. TPSS key voltage levels for substations with diode rectifiers, measured between the positive and negative buses of the rectifier and assuming nominal primary AC voltage at the TPSS, shall be as follows:

1. Nominal (100 percent load) voltage: 775 V DC
2. Light (1 percent) load voltage: 810 V DC. The initial voltage regulation of the transformer-rectifier unit shall be 4.5 percent, extending to at least 300 percent load
3. No-load voltage: maximum 835 V DC

B. TPSS key voltage levels for substations with thyristor-controlled rectifiers (TCR), measured between the positive and negative buses of the TCR, shall be as follows:

1. 845 V DC for loads in the 0 to 125 percent range
2. Inherent voltage regulation of 4.5 percent for loads exceeding the 125 percent level of the nominal current rating of the transformer-rectifier unit

C. Minimum acceptable train voltage: 525 V DC. The train voltage shall be measured between the contact rail and running rails at the respective train.

D. Maximum train voltage in regenerative braking mode: 900 V DC.

E. Maximum running rails potential at a stopped train at a passenger station: 80 V DC for normal and contingency operations. The voltage-to-ground of the running rails at stopped trains at passenger stations is effectively the train's touch potential, and it shall not exceed the specified limit. Under normal operations, observance of this limit shall be achieved by substation spacing. In contingency operations of the TES involving one TPSS out-of-service, the limit may also be enforced by operation of negative grounding devices.

13.5.5 Equipment Rating and Cable Sizing

TPSS equipment ratings and DC feeder sizes shall be determined using the maximum RMS loads from the simulation analysis performed for the worst-case contingency configuration of the TES affecting the particular equipment.

13.5.6 Simulation Analysis Requirements

The traction power simulation model used for TES design and analysis shall incorporate all elements of the transit system that affect TES performance, such as the following:

A. Passenger vehicle, including its dimensions, weight, tractive effort characteristic, regenerative braking, and forced reduced performance at low voltage.

B. Train operations plan, including consist sizes, headways, and passenger loading.

C. Alignment data, such as track configuration, passenger station locations, speed limits, and vertical profile.

D. DC system data, including positive and negative distribution systems configuration and parameters, and TPSS and GBS-related technical data.

E. Primary AC supply system data, including nominal and no-load voltages, and fault levels.

The TES simulation model shall solve the electrical network dynamically, accounting for train movements. Network solution time interval shall be one second.

For the given train operations plan, the simulation analysis shall consider operations with different dispatch times from the terminal stations, resulting in all possible timing offsets between trains moving in opposite directions. The analysis shall ensure that the worst-case minimum train voltages and maximum RMS currents possible for the specified headways are duly accounted for.

13.6 TRACTION POWER FACILITIES

The traction power facilities for the Project shall be of two types: traction power substations and gap-breaker stations.

TPSS will comprise all equipment necessary for conversion of the three-phase AC power to DC power, including equipment for protection, control, and ancillary systems. A TPSS typically includes utility metering equipment, AC switchgear, transformer-rectifier unit, DC switchgear, positive and negative busbars, negative grounding device (NGD), relay protection system, auxiliary power supply system, temperature control system, batteries and charger, security system, and substation house.

A GBS will consist of DC circuit breaker-type switchgear and associated auxiliary equipment. Gap breaker stations will be located at double crossover track interlocking where a TPSS is not required to provide switching capability and allow selective isolation of contact rail sections on the mainline and at turnouts.

As a GBS shall be similar to a TPSS, except that it will not have a transformer-rectifier unit and AC switchgear, the design criteria requirements are given for substations only. However, they shall apply equally for gap-breaker stations (excepting the equipment not required for a GBS).

All entrances and access doors to traction power facilities shall be supervised with an intrusion detection system as provided in Chapter 21, Fire and Intrusion Alarm Systems.

13.6.1 Substation Type

The TPSS shall be pre-fabricated, walk-in type, where all equipment is housed in one overall enclosure. The TPSS will be transportable with overall dimensions appropriate for transportation by truck in one unit, or at most two sections, which then would be assembled at the site. All equipment shall be installed and tested at the factory or assembly plant prior to shipment.

Substations and their sites shall be designed to minimize impact on areas in which they are located and to comply with the appropriate architectural, environmental, and commercial guidelines.

13.6.2 Utility Power Supply

Each TPSS shall be supplied from a single three-phase AC feeder from HECO at either 12.47 kV or 11.5 kV, depending on which medium-voltage utility system is available near the site.

The AC feeder size and installation shall be coordinated with HECO for each substation. HECO will provide the AC cables, metering equipment, and terminations, and make the connections to the TPSS. HECO will also provide the raceways (if underground feeder) or pole line to an interface point near but outside the TPSS site.

The TPSS design shall provide for the HECO energy and power demand metering requirements, which may include remote metering capability.

Electrical fault detection and protection for the traction electrification system shall be coordinated with HECO at each point of service.

The AC supply scheme shall be selected in cooperation with HECO. The primary criteria are as follows:

A. For enhanced reliability of the overall TES power supply, feeders to adjacent traction power substations shall be as independent as practically possible. As the 12.47/11.5 kV HECO distribution system is supplied from a 46 kV network, it shall be a project requirement that adjacent substations are fed from separate 46/12.47 kV or 46/11.5 kV step-down transformers.

B. Conduits, ducts, manholes, and cableways shall be provided for the AC supply cables from the TPSS to the HECO power grid. The cableway requirements and raceway interface point shall be coordinated with HECO.

13.6.3 Substation Enclosure

The TPSS enclosure shall be constructed of structural steel framework and sheet steel. It shall feature double-sided walls with thermal and acoustic insulation. The enclosure shall be also rainproof and shall meet the applicable ANSI standard requirements in that regard.

The outside of the TPSS enclosure, and all equipment installed on the outside walls (such as heating, ventilation, and air conditioning (HVAC) equipment) shall be painted dark green. The paint system shall be suitable for the specified atmospheric conditions with respect to air-induced corrosion, shall comply with Chapter 17, Corrosion Control, and shall have a life expectancy of not less than 20 years.

The substation enclosure design shall include provisions for replacement of all large equipment, such as circuit breakers and the rectifier transformer.

All substations shall be designed to meet basic safety and fire protection requirements as specified in Chapter 23, Fire/Life Safety enclosure.

The basic requirements to be incorporated into the enclosure design shall include the following:

A. Emergency access to and egress from the substation shall be in accordance with local fire codes and the Uniform Building Code.

B. Emergency lighting and exit signs shall be in accordance with local codes, the Uniform Building Code, and NFPA 130.

C. Substation shall be provided with an automatic fire detection system and portable fire extinguishers. They shall comply with the Hawaii Uniform Building Code and local codes.

D. Substation shall have two doors located at the opposite ends of the enclosure. Entry by unauthorized persons shall be prevented by means of locks and special keys.

E. Equipment access doors shall be provided to allow rear access from the outside to the DC feeder circuit breakers and utility metering compartment for ease of installation and maintenance.

13.6.4 AC Switchgear

The 15-kV class AC switchgear shall be of the metal-clad, draw-out type. The AC circuit breakers shall be vacuum type, 500 MVA class minimum suitable for the available utility voltage and short circuit current.

13.6.5 Transformer-Rectifier Unit

All traction power substations shall have one transformer-rectifier unit. The main components of the transformer-rectifier unit (TRU) will be rectifier transformer, traction rectifier, and interface transformer. The latter shall be required only in case of a diode rectifier.

The rectifier transformer shall be dry type, convection cooled, with one primary and two secondary windings suitable for double-way rectification per ANSI Circuit 31. The transformer shall be furnished with no-load taps providing for +/- 2.5 percent and +/- 5 percent transformation ratio adjustments relative to the neutral tap. The rectifier transformer shall be housed in a NEMA 1 indoor enclosure and shall be installed as part of the substation equipment lineup.

The traction rectifier shall be either silicon diode based or thyristor controlled type, connected in accordance with Circuit 31 of ANSI Standard C34.2, to deliver a 12-pulse, double-way output.

The rectifier shall be installed in a freestanding metal enclosure. Diode-based rectifiers shall be air-cooled by natural convection. Multi-speed, forced air ventilation shall be provided in case of a thyristor-controlled rectifier.

The rectifier transformers shall be three-winding, dry type, suitable for ANSI Circuit 31 rectification. Rectifier transformers shall be provided with multiple no-load taps to allow compensation for utility supply voltage variations.

The TRU rating shall be in accordance with the NEMA RI-9 extra heavy-duty traction load cycle, defined as follows: after reaching a steady state temperature, the TRU shall run at 150 percent of its rated load for two hours. During this two-hour period, five equally spaced loads of 300 percent shall be imposed on the unit for a one minute duration each. At the end of the two-hour cycle, a 450 percent load shall be imposed for 15 seconds. At the end of this duty cycle, there shall be no damage to the TRU or any of its components.

The traction rectifier shall be designed to provide the full power rating in case of failure of one diode (or thyristor) of the rectifier.

Safety interlocks shall be provided for the transformer and rectifier doors, automatically de-energizing the equipment if opened.

13.6.6 DC Switchgear

The DC switchgear shall be metal-enclosed type with safety enhancements, including automatic shutters on the stationary contacts of the DC circuit breakers. The maximum operating voltage of the DC switchgear shall be 1000 V DC.

DC circuit breakers shall be specifically designed for DC transit service and shall be used to provide fault clearing and isolation capability for the substations and contact rail sections.

The DC circuit breakers shall be single-pole, metal-enclosed, draw-out type; rated for 800 V dc nominal; and with maximum operating voltage of 1,000 V dc. The circuit breaker shall be high speed with short circuit interrupting capability per applicable IEEE standards.

DC feeder circuit breakers shall be equipped with direct acting instantaneous over-current release, load measuring, and automatic re-closure relaying. Transfer trip between substations shall also be provided.

Traction power substations shall feature a main (cathode) DC circuit breaker for increased operational flexibility and ease of TPSS maintenance.

13.6.7 Negative Grounding Device (NGD)

Under normal conditions, the TES shall operate with the negative buses of the traction power substations isolated from ground, which is mandatory for DC corrosion mitigation purposes. This will result in a “floating” negative return system.

Each TPSS shall be equipped with a NGD connected between the negative bus and the substation ground grid. The NGD shall be a thyristor switch operating normally open. The potential of the negative bus to ground shall be monitored continuously. If it exceeds a preset level, the NGD shall close, thereby temporarily grounding the negative bus and negative return system near the TPSS. The NGD shall be designed to open automatically upon cessation of current flow through the closed NGD.

13.6.8 Metering

The utility AC feeder line shall be provided with revenue metering in accordance with HECO requirements.

Indicating meters shall be provided in the TPSS to display the following:

A. AC phase currents

B. AC phase and line voltages

C. AC power demand meter with peak demand reset function

D. DC positive bus voltage (TPSS)

E. DC current (TPSS)

F. DC feeder current (for each positive feeder)

G. Contact rail voltage (as measured on the load side of each DC feeder breaker)

H. DC negative bus voltage to ground

13.6.9 Protection

The substation design shall incorporate protective devices to mitigate or preclude damage to TES equipment and avoid hazards to personnel in the event of overloads, faults, and other abnormal conditions. As a minimum, the following protection shall be provided:

A. Transformer/Rectifier Unit Protection:

1. AC over-current relays (phase and neutral)
2. Phase sequence (voltage phase unbalance) relay
3. Surge arresters in AC switchgear
4. Rectifier surge protection
5. DC reverse-current protection (main DC breaker). The reverse current- protection shall protect the rectifier in case of an internal fault fed from the outside (back-feed)
6. Rectifier diode-monitoring device
7. Transformer winding over-temperature relay
8. Rectifier diode over-temperature protection
9. Rectifier enclosure alive/grounded protection
10. DC switchgear enclosure alive/grounded protection

B. DC Feeder Breaker Protection

At a minimum, the following protective functions shall be provided for each DC feeder circuit breaker for detection and isolation of short-circuit type faults in the DC distribution system:

1. Instantaneous over-current trip: two types of this protection shall be provided: as a built-in instantaneous over-current release feature of the DC circuit breaker and as a function of an electronic relay. The latter shall be used for integration into the TES transfer-tripping logic (along with the other over-current based protective functions).
2. Low-level fault protection: current rate-of-rise protection shall be provided to detect low-level faults occurring at considerable distance from the substation. The rate-of-rise protective feature shall be able to discriminate between low-level remote faults and the inrush current of starting trains.

3. Timed over-current protection: Tripping of the DC feeder breaker shall be initiated when the load current exceeds a preset value continuously over a period of time greater than the associated time setting.

4. Load measuring: A load-measuring scheme shall be provided to automatically check the status of the line and prevent inadvertent closure onto a faulted line.

5. Transfer trip: A transfer-tripping scheme shall be provided for the mainline substations, which shall open all DC breakers feeding a faulted section upon short-circuit fault detection by any one of the circuit breakers connected to the same section. Transfer tripping is not applicable for the yard TES.

C. DC Enclosure Grounding

All DC switchgear cubicles, and the rectifier enclosure, shall be isolated from the ground and shall be bonded to a common copper ground bus connecting them to the substation ground mat through a protective device. The protective device may be either of the high-resistance or low-resistance grounding type. In either case, the protective device shall detect positive-to-enclosure faults, upon which the entire facility shall be de-energized. It shall also detect “enclosure grounded” type faults, upon which an alarm shall be raised.

13.6.10 Control and Indications

Substations shall normally operate unattended. Equipment shall be designed for remote supervision and control from the Operation Control Center (OCC) via a Supervisory Control and Data Acquisition (SCADA) system. The OCC, located on the premises of the yard, shall handle both the mainline TES and the yard system.

Local control capability shall be also provided. A local-remote selector switch shall be used in each substation to set the control mode for the entire facility. If the local-remote selector switch is in the “local” position, remote supervisory control “close” functions shall be disabled, and vice versa, if the switch is in the “remote” position, local “close” functions for the substation’s circuit breakers shall be blocked.

The circuit breaker “trip” functions, local or remote, shall not be affected by the local-remote selector switch position and shall always be available.

Substation lockout relays (Dev. 86) shall not be re-settable by the SCADA system.

A minimum 17-inch LCD screen shall be provided inside the TPSS showing in one location all key alarms and equipment status indications. The same alarms and status indications shall also be made available remotely at the OCC. The LCD screen shall be programmed to display, upon request, the TES single line diagram in the vicinity of the TPSS, including circuit breaker status, with actual circuit breaker and contact rail labels.

At a minimum, the alarms, status indications, and control functions listed in Table 13-1 shall be provided locally at each TPSS and remotely at the OCC. This list applies to a substation with an uncontrolled (diode-based) rectifier. In case of a TCR-type of substation, additional alarms shall be provided peculiar to the TCR equipment, such as alarms related to the forced ventilation system of the TCR, the TCR operation mode (single or double-bridge), and DC filter status.

Table 13-1 – TPSS Control and Indication Functions

Equipment	Control (Open/Close)	Status Indication/ Alarm
AC SWITCHGEAR		
AC Circuit Breaker	X	X
Loss of Utility Power		X
AC-DC CONVERSION EQUIPMENT		
Transformer Winding Over Temperature		X
Rectifier Over Temperature		X
Rectifier Diode Failure		X
Rectifier Surge Suppressor Failure		X
Rectifier Reverse Current Trip		X
Rectifier Enclosure Alive		X
Rectifier Enclosure Grounded		X
DC SWITCHGEAR		
Main (Cathode) Breaker	X	X
Feeder Breakers	X	X
Transfer Trip System Trouble		X
Feeder Breaker Re-Closure Failure		X
Feeder Breaker Multi-Function Relay Trouble		X
Lockout Relay Trip		X
DC Switchgear Enclosure Alive		X
DC Switchgear Enclosure Grounded		X
Contact Rail Energized (Each Section)		X
NGD		
NGD Trouble		X
NGD Closed		X
NGD High Current		X
MISCELLANEOUS		
TPSS Local Control Enabled		X
Loss of Low-Voltage Station Service Power		X
Intrusion Detection		X
Fire Alarm System:		
System Trouble		X
System Power Supply		X
Fire Alarm		X
Loss of 125 V DC Control Power		X
Loss of 24 V DC Control Power		X
125/24 DC/DC Converter Failure		X
125 V DC Battery-Charger System Trouble		X
TPSS High Air Temperature		X
TPSS Emergency Shutdown (from Local ETS)		X
Blue Light Station Trip		X

Separate enclosure alive/grounded protective devices shall be provided for the rectifier and DC switchgear.

At the OCC, the “Contact Rail Energized (Hot)” and “Contact Rail De-Energized (Cold)” indications shall be based on voltage measurements on the load side of all DC feeder breakers connected to the same electrical section. To ensure reliable indication of contact rail energized/de-energized status and avoid false indication due to individual equipment failure, logical functions shall be used taking into account inputs from all DC feeder breakers connected to the same section. For example, the “Contact Rail Section De-Energized” indication shall be based on all inputs from the associated DC feeder breakers confirming the “No Power” indication. Conflicting indications shall be used as an alarm for monitoring equipment type problems.

13.6.11 Climate Control System

The substations shall include a climate control system to maintain a target indoor aisle temperature of 77° F (25° C) and humidity not exceeding 50 percent at the extremes of outside temperature and humidity as specified in Chapter 3, Environmental Conditions and Chapter 19, Facilities Mechanical. These indoor design conditions shall be met with one critical component of the climate control system, such as the ventilation fan or air-conditioning unit, being out-of-service.

13.6.12 Miscellaneous

Low voltage equipment common with other electrical facilities for the Project, such as AC and DC distribution panels, lighting fixtures, receptacles, and low voltage wiring and raceways, shall comply with the requirements of Chapter 20, Facilities Electrical, unless superseded by the requirements of this chapter.

A. Lighting

Indoor lighting shall be provided using fluorescent fixtures with rapid-start, cool-white lamps. The interior lighting design shall provide for average maintained lighting intensity not less than 50 foot-candles vertical on the faces of the equipment. The uniformity ratio shall not exceed three to one.

Lighting shall be located so as not to create a glare on the front of the devices or meters. Locations of lighting fixtures shall be coordinated to avoid interference with overhead raceways or other major wiring and shall not be directly above switchgear, rectifiers, or transformers. The interior lighting shall be controlled by surface-mounted three-way or four-way switches at each entry door.

Exterior lighting shall consist of a weatherproof, wall-mounted area lighting fixture above each door. The fixture shall be UL-listed for wet locations and shall be equipped with a minimum 70-watt high-pressure sodium lamp and internal photoelectric control. The lighting fixture shall provide a low-glare, downward and outward light distribution resulting in a minimum illumination level of two foot-candles at ground level in front of the door. The exterior lighting shall be on a separate circuit and shall be controlled by a switch with three positions as follows: ON, OFF, and AUTO. In the AUTO position, the exterior lighting shall be controlled by a photoelectric cell.

B. Emergency Lighting

Emergency lighting shall be provided with a self-contained charger and battery sized for a minimum 90 minutes of operation. The emergency lighting shall provide at least one foot-candle at any point along the floor and shall conform to NFPA 101, Life Safety Code.

C. Convenience Outlets

Two duplex convenience outlets shall be conveniently located around the interior walls of the substation. One 20-amp duplex outlet near the switchgear and rectifier shall be separately circuited to permit use of a heavy-duty vacuum cleaner or up to 5-horsepower portable air compressor. One weatherproof duplex outlet located on an exterior wall of the substation shall be provided with outlet covers and tamper-proof screws.

D. Fire and Intrusion Alarm System

Fire and intrusion alarm systems shall comply with Chapter 21, Fire and Intrusion Alarm Systems.

A smoke detector shall be provided within the substation with provisions for local annunciation and remote indication.

An electro-mechanical intrusion detection device on each entry door shall be provided featuring local annunciation and remote indication.

E. Safety and Maintenance Equipment

Two portable fire extinguishers shall be provided in each substation enclosure.

The negative bus of each TPSS shall be connected to the ground grid through a negative grounding device, which shall ground the negative bus and thereby the running rails in the area upon detection of dangerous high voltage.

The TPSS design shall feature two ground test stations located near the opposite ends of the enclosure.

Separate test cabinets shall be provided for the testing of the draw-out AC and DC circuit breakers in each substation.

F. Auxiliary AC Power

Low-voltage AC power for the TPSS shall be three-phase, 120/208 V. It shall be provided via a station service transformer supplied from the substation’s primary AC bus. A low-voltage AC distribution panel shall be used to provide power to various equipment, such as air conditioning, interior and exterior lighting, battery charger, and convenience receptacles.

G. DC Control Power

Maintenance-free, 125 V DC batteries of the nickel-cadmium type shall be used as the power source for the protection devices and substation equipment control. The substation battery shall have sufficient capacity to support up to eight hours of normal substation operations, including two open-close cycles of the circuit breakers, in the event of low-voltage AC/DC conversion system failure.

The battery charger shall be three-phase and shall have adequate rating and low enough DC output ripple to support normal substation operations in the event of battery failure.

An external three-phase receptacle on the TPSS wall shall be provided to enable the battery charger to be supplied by a portable generator in the event of a long utility power outage.

Electronic equipment requiring 24 V DC control power shall be supplied from a 24-volt DC system powered off the 125-volt DC system via redundant 125/24-volt DC/DC converters. The DC/DC converter system shall feature N-1 redundancy, such that failure of a single converter shall not affect availability of the 24 V DC power supply to any equipment.

H. Air Temperature Monitoring

Air temperature detectors (two per TPSS enclosure) shall be installed to monitor the air temperature in the aisles.

I. Working Space

Working space is an area free of obstruction in front of the meters, service panels, and electric equipment, which provides safe access to all electric equipment and metering. Adequate working space shall be provided within the substation enclosure, as prescribed by equipment manufacturers and code requirements. Aisle width shall allow for convenient removal of the draw-out AC and DC circuit breakers.

J. DC Corrosion Control

The TES design shall incorporate provisions that mitigate DC stray currents and their impact on underground metal structures, as well as provide means of monitoring the DC stray currents according to the requirements of Chapter 17, Corrosion Control. To that effect, the TPSS shall include drainage panels as part of the corrosion control system with each panel featuring four drainage circuits. A drainage circuit shall comprise a disconnect switch, diode, current shunt, ammeter, and other accessories as detailed in Chapter 17, Corrosion Control. Raceways for the drainage circuits, extending from the drainage panel to a pullbox outside the TPSS, shall also be provided.

13.6.13 Substation Foundation

The design of the substation foundation shall conform to established civil and structural engineering practices, American Society for Testing Materials (ASTM) and American Concrete Institute (ACI) standards, local codes, and per Chapter 9, Structural. The substation foundation shall be structurally capable of withstanding the live and dead loads of the substation equipment and enclosure occurring during installation, operation, and maintenance of the substation.

The foundation design shall include adequate provisions for raceway interfaces and anchoring of the substation house to the ground.

The top level of the substation foundation shall not be below the 100-year floodplain.

13.6.14 Requirements for Gap Breaker Stations

Gap breaker station requirements shall be similar to those for a traction power substation, except that the gap breaker station will not have AC switchgear and a transformer-rectifier unit, and as such, does not require a medium-voltage power supply.

Gap breaker stations shall be of the common bus-type configuration and the DC switchgear configuration shall be similar to a TPSS.

Gap breaker stations shall be provided with low-voltage, three-phase AC power supply from HECO, either at 208 V or 480 V AC.

13.7 DC POWER DISTRIBUTION SYSTEM

The DC power distribution system includes the positive DC feeders from the traction power substations to the contact rail system, the contact rail system, the negative DC feeders from the substations to the tracks, and the running rails. Cross-bonds between the running rails of the different tracks, impedance bonds (if required, depending on the type of train control system), and raceways and associated appurtenances for the installation and routing of the feeder cables, are also part of the DC power distribution system.

13.7.1 Contact Rail System

A. The contact rail shall be top-running with electrical resistance not exceeding 0.002 ohms/1000ft at 20° C. The contact rail shall be able to carry 4,000 amperes continuously with temperature rise not exceeding 45° C above ambient air, assuming 2 ft/sec wind velocity.

B. Construction-wise, the contact rail shall be composite bi-metallic consisting of steel rail with aluminum bars fastened on both sides to its web.

C. The contact rail centerline shall be offset by 2 feet, 2 inches from the track gauge line. The contact rail height shall be 6 inches above the top of the running rail.

D. The contact rail shall be seated upon 7-inch-tall support insulators. The support insulator assembly shall be centered below the contact rail, and the insulator base shall be sufficiently wide to provide a stable arrangement for the rail. The contact rail and support insulator shall withstand without permanent deformation the stresses caused by the maximum short circuit currents, and thermal expansion and contraction due to variations in ambient temperature and heating from current flow.

E. Contact rail segments shall be joined with locking-type bolted connections. The contact rail joints shall not have misalignment or roughness. Bolted butt joints shall be ground smooth for minimum wear and abrasion of collector shoes.

F. Feeder connections to the contact rail shall be suitably designed, located, and attached to provide permanent connection without excessive protrusion from the side of the rail.

G. The contact rail shall be equipped with protective cover-board made of insulating material and enclosing the contact rail on the far side, top, and partially on the track side. The cover-board material, strength, and flammability shall meet applicable NFPA 130 requirements.

H. End approaches or ramps shall be provided at the ends of contact rail segments. Standard ramp length shall be 9 feet. At locations where train speed does not exceed 20 miles per hour (mph), ramps 5 feet long (short ramps) may be used. The inclination angle of the end approach ramps shall be 1.33 degrees for the standard ramp and 2.4 degrees for the short ramp, resulting in 2.5 inches elevation differential between the end points of the ramp.

I. The standard contact rail lengths shall not be less than 30 feet nor more than 50 feet. The rail shall have sufficient section modulus so that the maximum sag with a concentrated load of 30 pounds at midpoint between support insulators placed 10 feet apart shall not be more than 1/64 inch.

J. The contact rail system shall be furnished with expansion joints and anchor assemblies, designed and located in such a manner as to allow proper operation of the contact rail system over the entire range of possible rail temperatures (depending on ambient air temperature and current loading) without undue mechanical stresses or deformation. In long contact rail segments, expansion joints shall be provided at periodic intervals to allow thermal expansion and contraction. Contact rail sections between expansion joints and/or end ramps shall be anchored at their midpoint to maintain stability and alignment.

K. The contact rail shall be physically continuous between traction power facilities except at crosswalks, special trackwork areas, and sectionalizing gaps where it is necessary to have physical discontinuity in the contact rail. In addition, contact rail continuity shall be broken at wayside locations where the contact rail needs to switch sides for extra safety in coordination with emergency walkways.

L. At track turnouts where electrical continuity is required at the physical break in the contact rail, the adjacent contact rail segments are on the same side, and there is no crosswalk requirement, dip rail sections shall be used to avoid contact rail jumpers and associated accessories.

M. Except for the center of the double crossovers on the diverging tracks, the design of the entire contact rail system shall ensure that at least one current collector shoe of a two-car train is always in contact with the contact rail.

N. The contact rail system shall be divided into electrical sections separated by sectionalizing gaps. The contact rail within a given electrical section shall be electrically continuous throughout with physically separate segments being interconnected through jumper cables or via dip rail sections. Examples of such interconnections are at crosswalks, special trackwork locations, and at expansion joints where electrical continuity shall be provided by jumper cables with bolted connections to the contact rail.

O. Contact rail sectionalizing shall be implemented by means of definitely non-bridgeable gaps, also referred to as sectionalizing gaps. The sectionalizing gap shall be longer than the distance between the front and rear collector shoes of the passenger vehicle, which are expected to be in the range of 38 feet, 8 inches minimum to 42 feet, 0 inches maximum. At passenger stations, each non-bridgeable gap shall be located preferably on the approach side of the station. At stations where it is more economical to locate the sectionalizing gap in the normally accelerating zone, and at sectionalizing gap locations away from stations where trains would draw current exceeding 250 A/vehicle, the gap shall be of special segmented design including a short kicker rail section to prevent interruption of power to a passing car in normal operations. If one of the sections adjoining the segmented sectionalizing gap is de-energized, however, the gap shall provide adequate separation between the adjacent electrical sections that cannot be bridged by a single vehicle. Such separation shall be achieved by automatic removal of power from the kicker rail section in tandem with de-energizing of the adjoining long section.

P. Contact rail gaps not used for electrical sectionalizing, where in normal service a train will draw current greater than 250 A/vehicle, shall be bridgeable. Bridgeable gaps shall be sized so that considering the minimum shoe spacing of 38 feet, 8 inches for the vehicle, and the target shoe-ramp contact point on the end approach ramp with allowance for shoegear setting tolerances, the gap remains bridgeable by the collector shoes of a single vehicle.

Q. On the aerial structure, where feasible, the contact rail shall be installed on the side of the running rails opposite the emergency walkway. At passenger stations, the contact rail shall be installed on the side opposite the station platform.

R. For sectionalizing gaps of segmented design, the length of the kicker rail section and adjacent bridgeable gaps shall be coordinated in such a manner that with the kicker rail section de-energized a multi-vehicle train cannot form an electrical bridge through the segmented sectionalizing gap while straddling the gap.

13.7.2 Negative Return via Running Rails

A. Running rails will be used for returning the electrical current from the trains back to the substations.

B. Running rails shall be as defined in Chapter 5, Trackwork.

C. Both running rails of each track shall serve as negative return conductors, except if single-rail return is necessary for train control purposes in special short sections at track interlockings.

D. The running rail shall be welded continuously. If insulated joints need to be used at certain locations depending on the train control system type, the traction power DC continuity of the running rails shall be maintained by the use of impedance bonds.

E. All four running rails of the two tracks shall be cross-bonded for traction power return equalization purposes at the substations, and between substations at typical cross-bonding spacing in the 2,000 to 2,500 feet range. If the tracks cross-bonding needs to be through impedance bonds, the locations of these impedance bonds shall be coordinated with the design of the Automatic Train Control System.

Insulated joints in the running rails shall be installed at the entrances to the yard from the main line to create electrical isolation between the yard tracks and mainline tracks in normal operations.

Normally open bridging circuit breakers shall be installed in the yard's TPSS to allow electrical interconnection of the mainline and yard tracks under contingency operations (when the yard TPSS is out-of-service). The yard/mainline running rails gap bypass breaker shall be interlocked with the similar contact rail gap bypass breaker on the positive side to avoid operational mistakes of closing only the positive or negative bridging circuit breakers.

Insulated joints in the running rails shall also be installed outside the maintenance shops in the yard, to isolate electrically the running rails in the yard from those inside the shops, as the rails inside the shops shall be grounded for safety purposes.

Running rails of the mainline and in the yard shall be insulated electrically from ground for stray current reduction and corrosion mitigation purposes. For newly installed tracks, the distributed electrical resistance to ground shall not be less than 1,000 ohms/1,000 feet per single rail, or 500 ohms/1,000 feet per track.

13.7.3 DC Power Cables

A. Conductors for the DC feeders – positive and negative – shall be 2.4-kV insulated, unshielded cables, conforming to applicable industry standards (ICEA, NEMA, IEEE, and UL). The cables shall be suitable for installation in both wet and dry locations.

B. The DC feeders shall be sized based on the maximum RMS currents from the load flow study and ampacity de-rating considerations for the particular raceway system. DC feeder and jumper sizes shall be determined so that the temperature rating of the cables is not exceeded under normal or contingency operations of the TES.

C. Since the contact rail constitutes a vibrating mass, provision shall be made in the design of all DC cable terminations to prevent cable connection failures. The design shall use standard stranding feeder cables with a transition to extra-flexible stranding cables being provided for the final connection to the wayside contact rail system.

D. DC feeders and contact rail jumpers shall be of a common conductor size using multiple conductors to achieve the required ampacity. The standard cable size shall be selected to minimize installed cost.

13.7.4 DC Raceways

A. Traction power cables for positive and negative return feeders shall be laid or run in appropriate raceways, such as conduits, trays, cable trenches, or on racks through the substations. Such raceways shall provide an adequate cross-sectional area to permit a neat alignment of the cables and to avoid crossing or twisting.

B. Positive and negative feeders shall be installed in separate raceways and shall not share the same manhole or pullbox.

C. On trays, the cables shall be arranged in no more than two layers.

D. On racks, porcelain or synthetic insulators designed for such purpose shall be used in the supporting arms. Such supporting arms or racks shall be spaced to avoid excessive weight or pressures against the cable insulation.

E. The ends of all exposed conduits shall be sealed. All conduit stub-ups shall be protected against damage during construction operations.

F. DC feeder ductwork between traction power facility sites and the aerial guideway shall be buried underground and shall consist of polyvinyl chloride conduit encased in concrete. Design of ductwork, such as conduit size, design cable pull, maximum total angular turn, minimum embedment depth below grade, manhole spacing, and duct gradient, shall be in accordance with NEC requirements and as required to avoid excessive stress or jamming during cable pulling. Feeder ductwork shall be identified by a yellow warning tape 6 inches wide marked, “Warning – High Voltage” laid 12 inches above concrete encasement in backfill.

G. DC feeder ductwork shall be run as directly as practicable and shall be located to avoid interference with foundations, piping, and other similar underground work.

H. Rigid metallic conduit shall be used at bends in the routing and where the conduit is exposed.

Manholes, handholes, and pull boxes shall be located in such a manner as to facilitate installation of cables and avoid jamming or undue stress during cable installation.

The traction power DC positive and negative raceways shall contain one spare conduit per circuit.

13.8 TRACTION ELECTRIFICATION SYSTEM SAFETY

The design of the traction electrification system shall incorporate the requirements of Chapter 23, Fire/Life Safety, and the latest addition of the following safety codes, as administered by the City:

A. NFPA 101, Life Safety Code

B. NFPA 130, Standard for Fixed Guideway Transit and Passenger Rail Systems

C. NFPA 70, National Electrical Code

D. NFPA 72, National Fire Alarm Code

E. Hawaii Occupational Safety and Health Plan

F. IEEE 80, Guide for Safety in AC Substation Grounding

Prominent safety features of the TES design shall include an emergency trip system, equipment grounding practices, contact rail system design safety-oriented features, and limitations on train touch potentials.

13.7.1 Emergency Trip System

The TES shall include an emergency trip system that allows the contact rail to be de-energized from blue light stations located per criteria provided in Chapter 23, Fire/Life Safety.

Blue light stations shall include emergency trip stations as one of their main components. An emergency trip station (ETS) shall contain an easily identifiable pushbutton as activation device of a latch-in type with twist-to-release feature. Momentary change of status of the emergency trip pushbutton, in conjunction with simultaneous activation of an emergency call pushbutton, shall trigger the emergency trip process for de-energizing the tracks associated with the particular ETS and also raise an alarm in the OCC and initiate voice communications with the OCC. Restoration of power to the contact rail system shall be possible only after a mechanical reset of the activated ETS using the twist-to-release pushbutton.

The electrical circuit of each ETS shall be continuously supervised, and ETS-related electronic equipment shall have self-monitoring features. An "ETS equipment trouble" alarm shall be raised at the OCC in the event of a circuit continuity problem or ETS equipment failure.

Low voltage power supply to the emergency trip system equipment shall be from reliable sources, if available, such as essential power bus for train control or vital communications equipment. Low voltage power supply to adjacent blue light stations shall be as independent as possible so that loss of power to one blue light station does not affect adjacent blue light stations.

The emergency trip signal and associated alarms shall be conveyed to the required traction power facilities and OCC by the communication system through fiber-optic cables. The same fiber-optic links used for TES alarms and remote control shall be used for transmission of the emergency trip signals and alarms. In the TPSS/ GBS, the emergency trip signal shall be similar to a SCADA point and shall be used to trip without re-closing the required DC feeder circuit breakers.

Per NFPA 130 requirement, the blue light stations will also have provisions for voice communication to the OCC.

A. Location Criteria for Emergency Trip Stations on the Mainline

The locations of the emergency trip stations and associated blue light stations on the mainline shall be per criteria provided in Chapter 23, Fire/Life Safety.

The design of the emergency trip stations at station platforms shall be such as to prevent accidental or frivolous activation by the public.

At TPSS and GBS sites, the blue light station shall be mounted on the outside wall of the enclosure.

B. Location Criteria for Emergency Trip Stations in the Yard

The emergency trip stations and associated blue light stations in the yard shall be located per criteria provided in Chapter 23, Fire/Life Safety.

13.8.2 Negative Return System Grounding

The negative buses of the traction power substations and entire negative return system shall be floating relative to earth, except for a temporarily grounded TPSS negative bus by a negative grounding device (NGD). Such grounding shall occur if the potential to ground of the negative bus in a given substation exceeds the pre-set limit. The temporary grounding is a safety measure to guard against high rail potentials, which could be dangerously high, especially if due to positive-to-ground system faults.

13.8.3 Substation Grounding

Traction power substations shall be equipped with a ground grid designed to meet the touch and step potential safety limits per applicable IEEE codes (e.g., IEEE Standard 80). For AC equipment, including AC switchgear and rectifier transformers, non-energized metal parts and enclosures shall be solidly grounded to the ground grid.

Metal enclosures for traction power rectifiers and DC switchgear shall be installed so they are insulated from the ground and shall be connected to the substation ground mat (or grid) through a high-resistance or low-resistance structure ground relay (Device 64). The structure ground relay shall be capable of detecting both positive to frame faults, as well as accidental ground connections of the DC switchgear frames. Positive to frame fault detection shall result in immediate shutdown of the traction power facility, while accidental ground detection shall be only alarmed.

The grounding requirements for the incoming AC feeder, as well as the service connection requirements at each traction power substation, shall be coordinated with HECO.

13.8.4 Maintenance Shop Track Grounding

Running rails inside shop facilities shall be grounded. Insulated joints shall be installed at the entrances to the shop facilities to prevent any electrical connection between the grounded rails inside the shop and the running rails in the yard.

13.8.5 Contact Rail Position Relative to Running Rails

The contact rail through passenger stations shall be located at trackside opposite the station platform. On the aerial guideway, the contact rail shall be located on the opposite side of the emergency walkway, except where this is not possible at the special track work areas.

13.8.6 Contact Rail Appurtenances

Cables connecting the contact rail, potheads, and energized hardware shall be covered with insulating material and installed so as not to present a tripping or electrical hazard to personnel on the walkway.

13.8.7 Protective Contact Rail Cover-Board

For safety, and also to protect against debris, the contact rail will be provided with protective cover-board. The cover-board shall enclose the contact rail on the far side from the track and the top, as well as partially on the trackside.

The protective cover-board shall meet NFPA 130 requirements concerning flammability and structural integrity (weight carrying capability).

The protective cover-board design shall provide for adequate safety clearances and shall not obstruct the movement of the train's current collector shoes.

The protective cover-board shall extend a minimum of 12 inches beyond the tip of the contact rail end approach (contact rail ramp).

13.8.8 Safety Clearances

Safety-related clearances between emergency walkways, crosswalks, and cross-paths on one side, and the contact rail on the other, shall meet the relevant requirements of Chapter 23, Fire/Life Safety.

13.8.9 Dummy Cover-board

Dummy cover-board (cover-board without contact rail) shall be provided in areas along the tracks where personnel may be exposed to accidental contact with energized car paddles, such as train operator access areas in tail tracks and train cleaners pathways in the yard.

13.8.10 Train Touch Potential Limit

The TES shall be designed so that the maximum potential to ground at any train at a passenger platform during station dwell does not exceed 80 V DC during normal operations or contingency operations (the latter with one TPSS out of service).

END OF CHAPTER

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(Project)

DESIGN CRITERIA

CHAPTER 14

TRAIN CONTROL

TO BE DEVELOPED

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CHAPTER 15

COMMUNICATIONS AND CONTROL

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CHAPTER 17

CORROSION CONTROL

April 3, 2009

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17.1 GENERAL

17.1.1 Introduction

This Chapter describes the design criteria for corrosion control. Corrosion control is required to prevent premature corrosion failures on transit-system facilities, on metallic and concrete pipes, and on other underground structures. Such measures will also minimize stray current levels and their effects on underground and above-grade structures. Types of corrosion control include mitigation for stray currents and protection against atmospheric and underground corrosion. Corrosion-control systems should be economical to install, operate, and maintain.

17.1.2 Goals

Corrosion-control design criteria encompass all engineering disciplines applied to the Project.

The criteria are separated into three areas: stray current corrosion, soil corrosion, and atmospheric corrosion. The design criteria for each of these categories, and their implementation, shall meet the following objectives:

A. Realize the design life of system facilities by avoiding premature failure caused by corrosion

B. Minimize annual operating and maintenance costs associated with material deterioration

C. Provide continuity of operations by reducing or eliminating corrosion-related failures of systems and subsystems

D. Minimize detrimental effects to facilities belonging to others that may be caused by stray earth currents from transit operations

17.1.3 Reference Data

All design relating to implementation of the corrosion-control requirements shall conform to or exceed the requirements of the latest versions of codes and standards identified in these criteria. Standards, codes, and recommended practices for corrosion control include the publications and/or codes issued by the following:

A. The National Association of Corrosion Engineers International

B. National Fire Protection Association

C. American National Standards Institute

D. American Standards for Testing Materials

E. American Water Works Association

F. American Electric Railway Association

G. U.S. Department of Transportation

H. Steel Structures Painting Council

I. Institute of Electrical and Electronic Engineers

J. Underwriters Laboratories, Inc.

K. The Occupational Safety and Health Act

L. National Electrical Code

M. Military Specifications

N. National Electrical Manufacturer's Association

O. National Electrical Safety Code

Several Local and State codes may also apply. Designers shall consult these publications and provide systems in accordance with the most stringent applicable code or industry practice.

17.2 SYSTEM INTERFACES

Corrosion-control engineering shall be coordinated with other disciplines, including mechanical, utility, electrical, civil, structural, trackwork, electrification, signaling, and communications designs.

17.3 STRAY CURRENT CONTROL

This section provides criteria for designs to minimize the corrosive effect of stray current from transit operations on transit structures and adjacent structures owned by others. Criteria in this category apply to measures installed with the traction power system and trackwork to ensure that stray earth traction currents do not exceed allowable levels. They are based on anticipated stray earth traction current levels and the characteristics of fixed facilities and other buried structures.

Stray current control shall reduce or limit the level of stray currents at the source, under normal operating conditions, rather than trying to mitigate the corresponding effects (possibly detrimental) that may otherwise occur on transit facilities and other underground structures.

Stray current control shall be based on the following principles:

A. Increasing the conductivity of the return circuit

B. Increasing the resistance between the return circuit and the earth

C. Increasing the resistance between the earth and underground metallic structures

D. Increasing the resistance of underground metallic structures

17.3.2 Traction Power System

The traction power supply system shall be designed as a dedicated system, providing power solely to the transit rail line. Joint use of traction power facilities, except for common civil structures, is not permitted. Individual traction power supply for the third-rail system shall be designed with electrically isolated, independent subsystems for the mainline, yard, and shop.

17.3.2.1 Traction Power Substations (Mainline)

See Chapter 13, Traction Electrification, for traction power substation requirements.

A stray current drainage bus (copper) and drainage circuits shall be installed within each traction power substation in an area adjacent to the negative bus. The drainage bus shall be electrically insulated from the building's structural steel and other grounded facilities within the substation.

Four 2-inch conduits shall be installed from within the substation enclosure adjacent to the stray current drainage bus to a pullbox located underground adjacent to the substation. Insulated cables shall be installed from the stray current drainage bus into the stray current drainage pull box through polyvinylchloride (PVC) conduits. The number and size of cables and the number of drainage circuits shall depend on structures in the area and shall be determined during Final Design.

Provisions shall be included to continually monitor track-to-earth potentials at intervals not greater than 1.5-miles. Monitoring facilities shall be located at traction power substations and at intermediate locations, such as passenger stations, if necessary, to maintain the recommended spacing. Permanently installed recorders or provisions for connection to a Supervisory Control and Data Acquisition system shall be considered.

17.3.2.2 Positive Distribution System

Individual and separate positive distribution systems shall be provided for the mainline, yard, and shop. These individual positive distribution systems shall be designed for electrical isolation between the following:

A. Mainline and yard

B. Mainline and shop

C. Yard and shop

Each individual and separate positive distribution system shall normally be operated as an electrically continuous positive bus with no electrical discontinuities, except during emergency or fault conditions.

Third-rail contact systems, consisting primarily of support pedestals and pads, contact rail insulators, and contact rails, shall have a minimum in-service resistance to earth of 1000 mega ohms per foot (mohm/ft). Individual contact rail insulators shall have a minimum resistance of 100 mohm.

17.3.2.3 Mainline Negative Return System

A. Running Rails

To minimize and mitigate corrosion of transit rails, reinforced concrete corrosion control and mitigation measures shall be systematically implemented and coordinated.

The recommended rail industry mitigation methods, based on the *Track Design Handbook for Light Rail Transit*, are as follows:

1. Weld rail continuously
2. Install insulating pads and clips on concrete crossties
3. Install insulated rail fastening system for timber crossties and switch timber
4. In ballasted track area, keep the ballast clean and well drained, and maintain the ballast at a minimum of 1 inch below the bottom of the rails
5. Install bonding rail jumpers at mechanical rail connections (especially special trackwork)
6. Install cross-bonding between rails and between tracks to maintain equal potentials of all rails

B. Ancillary Systems

Switch machines, signaling devices, train communication systems, and other devices or systems that may contact the rails shall be electrically isolated from earth. The criteria shall be met through the use of dielectric materials electrically separating the devices/systems from earth, such that the criteria given in this section are met. Recommended mitigation methods include the following:

1. Insulate the impedance bond tap connections from the housing case
2. Insulate switch machines at the switch rods

17.3.3 Transit Fixed Facilities

Bridge-type aerial structure using columns and bearings with direct fixation track and insulated rail fasteners will be used for mainline construction. Stray current control requirements shall include the following:

A. Electrical continuity of deck/girder reinforcing steel shall be provided by welding all longitudinal lap splices.

B. Longitudinal deck/girder reinforcing steel shall be electrically interconnected by welding to transverse collector bars installed at each side of breaks in longitudinal reinforcing, such as at expansion joints, hinges, abutments, and each end of the aerial structure. Transverse collector bars installed on each side of a break shall be electrically interconnected with a minimum of two copper AWG No. 4 bond cables.

C. Additional transverse collector bars shall be provided at intermediate locations along the structure to maintain a maximum spacing of 250 feet between collector bars.

D. Test facilities shall be provided at each end of the structure and at intermediate locations to maintain a maximum spacing of 250 feet between test points. The facilities will house test wires from the collector bars.

E. Second pour/plinth pad steel reinforcing shall be epoxy-coated and shall be isolated from the electrically continuous steel reinforcement of first pour concrete.

F. Anchor plates for pre- or post-tensioned cables are to be electrically interconnected to electrically continuous reinforcing steel by welding AWG No. 4 cable between each anchor plate and the longitudinal reinforcement.

17.3.2.1 Utility Structures

All piping and conduit shall be nonmetallic, unless metallic facilities are required for specific engineering purposes. There are no special provisions required if nonmetallic materials are used.

A. Replacement/Relocated Facilities

Corrosion-control requirements for buried utilities installed by the utility owner/operator as part of transit construction shall be the responsibility of the individual utility owner/operator. Minimum stray current corrosion-control criteria, when guidance is requested by the utility owner/operator, shall be in accordance with the paragraph titled “Existing Utility Structures” below.

Relocated or replaced utilities, installed by transit contractors as part of a contractual agreement between the transit agency and the utility, shall be installed in accordance with the utility owner’s specifications and shall include the following minimum provisions:

1. Electrical continuity through the installation of insulated copper wires across all mechanical joints for which electrical continuity cannot be ensured
2. Electrical access to the utility structure via test facilities installed at nominal 200 foot intervals

These provisions are applicable to ferrous and reinforced concrete cylinder piping. Other materials and structures will require individual review.

The need for additional measures, such as electrical isolation, application of a protective coating system, installation of cathodic protection, or any combination of the preceding, shall be based on the characteristics of the specific structure and shall not adversely affect the existing performance within the environment.

B. Existing Utility Structures

The need for stray current monitoring facilities shall be determined by the utility operators. If utilities require assistance, the test facilities may be installed at select locations for the purpose of evaluating stray earth current effects during start-up and revenue operations.

17.4 SOIL CORROSION CONTROL

This section provides criteria for the design of systems and measures to prevent corrosion of transit system fixed facilities due to contact with area soil, rock, and groundwater. Designs shall be based on achieving a minimum 50-year desired useful life for buried structures, with the exception of a 100-year design life for the transit fixed facilities through consideration of the factors presented below.

17.4.1 Requirements

Soil samples should be obtained in conjunction with geotechnical testing along the track alignment. The soil samples should be analyzed for resistivity (or conductivity), moisture content, pH, and chloride and sulfate ion concentrations.

Structures shall be protected against environmental conditions by system design and the use of coatings, insulation, cathodic protection, electrical continuity, or a combination of the preceding, as appropriate.

17.4.2 Materials of Construction

All pressure and non-pressure piping and conduit in contact with soil shall be non-metallic, unless metallic materials are required for specific engineering purposes.

Aluminum and aluminum alloys shall not be used in direct burial applications.

The use of dissimilar metals should be avoided.

Material for backfilling concrete or ferrous structure excavations shall meet the following criteria:

A. pH 6 to 8

B. Maximum chloride ion concentration of 250 parts per million (ppm)

C. Maximum sulfate ion concentration of 200 ppm

17.4.3 Safety and Continuity of Operations

Corrosion-control protection shall be required for those facilities where failure of such facilities caused by corrosion may affect the safety or interrupt the continuity of operations.

17.4.4 Accessibility of Installations

Permanent test facilities installed with certain corrosion-control provisions shall be accessible after installation, allowing for periodic maintenance and monitoring.

17.4.5 Materials and Methods

The following paragraphs establish the materials and methods to be used for soil corrosion control.

17.4.5.1 Coatings

A. Coatings for Metallic Structures

Coatings specified for corrosion control of buried metallic facilities shall satisfy the following criteria:

1. Minimum volume resistivity of 10,000,000,000 ohm-centimeters (1×10^{10} ohm-centimeters)

2. Minimum thickness as recommended for the specific system, but not less than 15 mils (1 mil = 1/1000 of an inch).

3. A chemical or mechanical bond to the metal surface. Pressure-sensitive systems are not acceptable; non-bonding systems may be used in special instances

4. Minimum five-year performance record for the intended service

5. Mill application wherever possible, with field application of a compatible paint or tape system

6. Mechanical characteristics capable of withstanding reasonable abuse during handling and earth pressure after installation for the design life of the system

B. Generic coating systems include, but are not limited to, the following:

1. Extruded polyethylene/butyl-based system

2. Coal-tar epoxies (two-component systems)

3. Polyethylene-backed butyl mastic tapes (cold applied)

4. Bituminous mastics (airless spray)

5. PVC coating for conduit

C. Coatings for Concrete Structures

Evaluate the need for coatings as a measure of corrosion control for concrete structures in contact with soil or groundwater. Such structures may or may not realize significant benefit from the application of protective coatings. Such coatings would need to withstand the stresses (e.g., abrasion, impact, or less than ideal application conditions) the proposed installation techniques would impose.

Selection of coating systems as corrosion protection for reinforced concrete structures must consider the intended purpose of the coating, the application options available based upon proposed construction techniques, and performance history of both the generic coating class (e.g., epoxy, epoxy-novolac, and sealant/penetrant) and the specific product.

D. Barrier coatings specified for corrosion control of concrete facilities shall satisfy the following criteria:

1. Minimum volume resistivity of 10,000,000,000 ohm-centimeters ($1x10^{10}$ ohm-centimeters)

2. Minimum thickness as recommended for the specific system

3. A chemical and mechanical bond to the concrete surface

4. Minimum five-year performance record for the intended service

5. Ability to perform when applied in the manner construction techniques will require (e.g., field application or uncontrolled atmosphere).

6. Mechanical characteristics capable of withstanding reasonable abuse during handling and earth pressure after installation for the design life of the system

17.4.5.2 Electrical Insulation of Piping

Devices used for electrical insulators for corrosion control shall include nonmetallic inserts, insulating flanges, couplings, unions, and/or concentric support spacers. Devices shall meet the following criteria:

A. A minimum resistance of 10 meg-ohms prior to installation

B. Sufficient electrical resistance after insertion into the operating piping system such that no more than 2 percent of a test current applied across the device flows through the insulator, including flow through conductive fluids, if present.

C. Mechanical and temperature ratings equivalent to the structure in which they are installed

D. Internal coating, except completely non-metallic units, with a polyamide epoxy for a distance on each side of the insulator equal to two times the diameter of the pipe in which they are used. Where conductive fluids with a resistivity of less than 2,000 ohm-centimeters are present, internal coating requirements shall be based on a separate evaluation.

E. Devices (except non-metallic units) buried in soils shall be encased in a protective coating.

F. Devices (except non-metallic units) installed in chambers, or otherwise exposed to partial immersion or high humidity, shall have a protective coating applied over all components.

G. Inaccessible insulating devices, such as buried or elevated insulators, shall be equipped with accessible permanent test facilities.

A minimum clearance of 12 inches shall be provided between new and existing metallic structures. When conditions do not allow a 12-inch clearance, the design shall include special provisions to prevent electrical contact with existing structures.

17.4.5.3 Electrical Continuity of Piping

Electrical continuity shall be provided for all non-welded metallic pipe joints. Pipelines with bonded joints shall be electrically insulated from existing metallic pipelines at the point of connection.

Use direct-burial, insulated, stranded, copper wire with the minimum length necessary to span the joint being bonded.

A. Base the wire size on the electrical characteristics of the structure and resulting electrical network to minimize attenuation and allow for cathodic protection

B. Use a minimum of two wires per joint for redundancy

C. Connect to the pipe with a thermite weld

D. Repair damaged pipe coating

E. Coat weld area and exposed conductor

17.4.5.4 Cathodic Protection

Use sacrificial galvanic anodes for pipeline cathodic protection. Impressed current systems shall be used only when the use of sacrificial systems is not technically and/or economically feasible. Cathodic protection schemes that require connection to the transit system negative return system, in lieu of using a separate, isolated anode groundbed, are not permitted.

Cathodic protection system design shall be based on theoretical calculations that include the following parameters:

A. Estimated percentage of bare surface area (minimum 1%)

B. Cathodic protection current density (minimum 1.0 ma/ft^2 of bare surface area)

C. Estimated current output per anode

D. Estimated total number of anodes, size, and spacing

E. Minimum anode life of 50 years (minimum 50% efficiency)

F. Calculated anode groundbed resistance

Impressed current rectifier systems shall be designed using variable voltage and current output rectifiers. Rectifiers shall be rated at a minimum of 50% above calculated operating levels to overcome a higher-than-anticipated anode groundbed resistance, lower-than-anticipated coating resistance, or presence of interference mitigation bonds. Other conditions that may result in increased voltage and current requirements shall be considered.

Test facilities consisting of a minimum of two structure connections, one reference electrode connection, conduits, and termination boxes shall be designed to permit initial and periodic testing of cathodic protection levels, interference currents, and system components (anodes, insulating devices, and continuity bonds). The designer shall specify the locations and types of test facilities for each cathodic protection system.

17.4.6 Structures and Facilities

The following paragraphs establish the protective measures to be considered for utilities and buried structures.

17.4.6.1 Ferrous Pressure Piping

All new buried cast iron, ductile iron, and steel pressure piping shall be cathodically protected. System design shall satisfy the following minimum criteria:

A. Application of a protective coating to the external surface of the pipe and mortar lining.

B. Electrical insulation of pipe from interconnecting pipe and other structures, and segregation into discrete electrically isolated sections depending upon the total length of piping.

C. Electrical continuity through the installation of copper wires across all mechanical pipe joints other than intended insulators. The size of the bond wire should be selected based on the pipe's material and diameter.

D. Permanent test/access facilities installed at all insulated connections to allow for verification of electrical continuity, electrical effectiveness of insulators and coating, and evaluation of cathodic protection levels. Additional test/access facilities shall be installed at intermediate locations, either at intervals not greater than 200 feet, or at greater intervals determined on an individual structure basis.

E. Number and location of anodes and size of rectifier, if required, shall be determined on an individual structure basis.

F. Electrically insulate pipe immediately inside wall penetration into underground facilities.

17.4.6.2 Copper Piping

Buried copper pipe shall be electrically isolated from non-buried piping, such as that contained in a station structure, through use of an accessible insulating union installed where the piping enters through a wall or floor. Pipe penetrations through the walls and floors shall be electrically isolated from building structural elements. The insulator should be located inside the structure and not buried.

17.4.6.3 Gravity Flow Piping (Non-Pressured)

A. Cast or ductile iron piping shall be designed and fabricated to include the following provisions:

   1. An internal mortar lining with a bituminous coating on ductile iron pipe only (not required for cast iron soil pipe)

   2. A bonded protective coating or unbonded dielectric encasement on the external surfaces in contact with soils (American Water Works Association Standard C105)

   3. A bituminous mastic coating on the external surfaces of pipe 6 inches on each side of a concrete/soil interface

B. Reinforced concrete non-pressure piping shall include the following provisions:

1. Water/cement ratios meeting the minimum provisions of the American Water Works Association
2. Maximum 250 ppm chloride concentration in the total concrete mix (mixing water, cement, admixture and aggregates)
3. Use Type I cement

17.4.6.4 Electrical Conduits

Underground electrical power conduits shall be of non-metallic construction (PVC, fiberglass, or similar material). Where metallic conduits are necessary, the conduit shall be of galvanized rigid steel construction with a PVC topcoat (10 mils). The PVC coating is not required when conduits are installed in concrete. Three inches of concrete cover is required. Electrical continuity should be established for metallic conduits through use of standard threaded joints or bond wires installed across non-threaded joints.

17.4.6.5 Hydraulic Elevator Cylinders

Steel hydraulic elevator cylinders shall be designed, fabricated, and installed to meet the following criteria:

A. External protective coating resistant to deterioration by petroleum products (hydraulic fluid).

B. Outer concentric fiberglass-reinforced plastic casing. Casing shall be designed to prevent moisture intrusion (including the bottom) and to withstand physical conditions.

C. Sand fill between the cylinder and fiberglass-reinforced plastic casing shall be installed and shall remain dry. It shall have a minimum resistivity of 25,000 ohm-centimeters, a pH between 6 and 8, and a maximum chloride content of 250 ppm.

D. Cathodic protection through the use of sacrificial anodes installed in the sand fill.

E. Permanent test facilities installed on the cylinder, anodes, and earth reference to permit evaluation, activation, and periodic re-testing of the protection system.

F. Removable moisture-proof sealing lid installed on the top of the casing prior to installation of the cylinder. The top of the casing shall be permanently sealed against moisture intrusion after installation of the cylinder.

17.4.6.6 Buried Concrete/Reinforced Concrete Structures

The design of cast-in-place concrete structures shall be based on the following provisions:

A. Use of Type I cement. ASTM C 452-75 and American Concrete Institute (ACI) Publication SP-77, *Sulfate Resistance of Concrete,* should be used as guidelines for evaluating the sulfate resistance of concrete mixes with non-standard cement types.

B. Water/cement ratio and air entrainment admixture in accordance with specifications presented in the structural criteria to establish a dense, low permeability concrete. Refer to applicable sections of ACI 201.2R, *Guide to Durable Concrete*. Concrete to be in contact with soil or groundwater shall have a water/cement ratio of not greater than 0.45.

C. Maximum chloride concentration of 250 ppm in the total mix (mixing water, aggregate, cement, and admixtures). The concrete mix should be such that the water soluble and acid soluble chloride concentrations at the concrete/reinforcing steel interface do not exceed 0.15 and 0.2% by weight of cement, respectively, over the life of the structure. Refer to applicable sections of ACI 222R, *Corrosion of Metals in Concrete.*

D. Concrete cover over reinforcing steel shall comply with ACI codes. Provide a minimum of 2 inches of cover on the soil/rock side of reinforcement when pouring within a form and a minimum of 3 inches of cover when pouring directly against soil/rock or excavation support systems.

E. The need for additional measures, as a result of localized special conditions, shall be determined individually. Additional measures may include application of protective coatings to concrete or reinforcing steel, or both.

Design of precast facilities, such as vaults and manholes, must be reviewed to determine alternative criteria when they cannot be practically modified to meet these provisions.

17.4.6.7 Support Pilings

The following is applicable only to support piling systems that are to provide permanent support. Pilings used for temporary support do not require corrosion-control provisions.

A. Designs based on the use of metallic supports exposed to the environment, such as H or soldier piles, shall include the use of a barrier coating. The need for special measures, such as cathodic protection, shall be determined individually based on the type of structure, analysis of soil borings for corrosive characteristics, and the degree of anticipated structural deterioration caused by corrosion.

B. Reinforced concrete pilings, including fabrications with prestressed members, shall be designed to meet the following minimum criteria:

C. Concrete to be in contact with soil or groundwater shall have a water/cement ratio of not greater than 0.45.

D. Restrictions on chloride concentrations for concrete with non-prestressed members shall be in accordance with the section above regarding buried concrete/reinforced concrete structures.

E. Restrictions on chloride concentrations for concrete with prestressed members shall be in accordance with the section above regarding buried concrete/reinforced concrete structures, with exception that the concrete mix should be such that the water-soluble and acid-soluble chloride concentrations at the concrete/prestressed steel interface do not exceed 0.06 and 0.08% by weight of cement, respectively, over the life of the structure. Refer to ACI 222R, *Corrosion of Metals in Concrete*.

F. There shall be a minimum of 3 inches of concrete cover over the outermost reinforcing steel, including prestressing wires, if present.

Concrete-filled steel-cylinder columns, where the steel is an integral part of the load-bearing characteristics of the support structure, shall be designed considering the need for special measures, such as increased cylinder wall thickness, external coating system, and/or cathodic protection. The design shall be determined individually based on type of structure, analysis of soil borings for corrosive characteristics, and the degree of anticipated structural deterioration caused by corrosion. Chloride restrictions shall be in accordance with the section above regarding buried concrete/reinforced concrete structures.

17.4.6.8 Reinforced Concrete Retaining Walls

Cast-in-place concrete retaining walls shall be in accordance with the requirements in the above section regarding buried concrete/reinforced concrete structures.

Modular-type retaining walls shall meet the requirements in the above section regarding buried concrete/reinforced concrete structures, as well as the following requirements (or be reviewed individually to determine alternative criteria when they cannot be practically modified to meet some or all of the provisions specified below):

A. Embedded and buried steel reinforcing members of the modules shall be constructed without special provisions for establishing electrical continuity.

B. Steel-reinforcing strips of adjacent modules shall not be electrically interconnected. The reinforcing strips should be coated with a fluidized-bed epoxy resin system or coal-tar epoxy system.

C. Tie-strips shall be coated with a fluidized-bed epoxy resin system or coal-tar epoxy system prior to module construction.

D. Longitudinal reinforcing steel within precast concrete parapets and cast-in-place junction slabs shall not be made electrically continuous.

17.5 ATMOSPHERIC CORROSION CONTROL

17.5.1 General

Criteria in this category apply to systems or measures installed to mitigate corrosion caused by local climatological conditions and air pollutants.

A. Coatings shall have established performance records for the intended service and be compatible with the base metal to which they are applied.

B. Coatings shall be able to demonstrate satisfactory gloss retention, color retention, and resistance to chalking over their minimum life expectancies.

C. Coatings shall have minimum life expectancies, defined as the time prior to major maintenance or reapplication, of 15 to 20 years.

17.5.2 Metallic-Sacrificial Coatings

All carbon and alloy steel assemblies, fixtures, and conduits shall be hot-dip galvanized. Where appropriate for aesthetic reasons, such items shall also receive an organic overcoat. Use dielectric devices between dissimilar metal combinations.

17.5.3 Organic Coatings

Organic-coating systems shall consist of a wash primer (for galvanized and aluminum substrates only), a primer, intermediate coat(s), and a finish coat. Acceptable organic coatings, for exposure to the atmosphere, are as follows:

A. Aliphatic polyurethanes

B. Vinyl copolymers

C. Fusion-bonded epoxy polyesters, polyethylenes, and nylons

D. Acrylics, where not exposed to direct sunlight

E. Alkyds, where not exposed to direct sunlight

F. Epoxy as a primer where exposed to the atmosphere or as the complete system where sheltered from sunlight

17.5.4 Conversion Coatings

Conversion coatings, such as phosphate and chromate coatings, shall be used as pretreatments only for further application of organic coatings.

17.5.5 Ceramic-Metallic Coatings (Cermets)

This hybrid-type coating system is acceptable for use on metal panels and fastening hardware.

17.5.6 Sealants

All crevices shall be sealed with a polysulfide, polyurethane, or silicone sealant.

17.5.7 Barrier Coating System

A. Use one of the following barrier coating systems where corrosion protection is needed but appearance is not a primary concern:

1. Near white blast surface according to SSPC-SP 10. Follow with a three-coat epoxy system.
2. Commercial blast surface according to SSPC-SP 6. Follow with a two-coat inorganic zinc and high build epoxy system.

3. Near white blast surface according to SSPC-SP 10. Follow with a three-coat epoxy zinc, high-build epoxy system.

4. Apply all coatings according to manufacturer's specifications.

B. Use one of the following barrier coating systems where corrosion protection and good appearance are needed.

1. Near white blast surface according to SSPC-SP 10. Follow with a three-coat inorganic zinc, high-build epoxy, and polyester urethane system.

2. Near white blast surface according to SSPC-SP 10. Follow with a three-coat vinyl system.

3. Commercial blast surface according to SSPC-SP 6. Follow with a three-coat epoxy zinc, high-build epoxy and polyester urethane system.

4. Commercial blast surface according to SSPC-SP 6. Follow with a three-coat epoxy zinc, high-build epoxy and acrylic urethane system.

5. Apply all coating according to manufacturer's specifications.

END OF CHAPTER

Honolulu High-Capacity Transit Corridor Project

(Project)

DESIGN CRITERIA

CHAPTER 18

YARD AND MAINTENANCE FACILITIES

TO BE DEVELOPED

Honolulu High-Capacity Transit Corridor Project

(Project)

DESIGN CRITERIA

CHAPTER 19

FACILITIES MECHANICAL

April 3, 2009

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19.0 FACILITIES MECHANICAL

19.1 GENERAL

19.1.1 Introduction

This chapter describes the functional and design requirements for the mechanical systems to provide ventilating, air conditioning and plumbing for the Project's facilities. It is intended to promote uniformity of design and to standardize the type and location of mechanical equipment.

These criteria cover the mechanical functional requirements, operation, and control for the following facilities, which can be grouped into three broad categories: ancillary spaces, operations control center, and parking structures. The environmental control space design requirements for all facilities are included in the Table 19-2. The major types of facilities covered under this design narrative are as follows:

A. Maintenance yards and shops (includes maintenance storage facility, maintenance of way, and train wash)

B. Traction power substations (TPSS)

C. Ancillary spaces

D. Stations and transit centers

E. Parking structures

The mechanical requirements for the transit vehicle are respectively prescribed in the following chapters of these criteria: Chapter 12, Revenue Vehicles, Chapter 14, Train Control, Chapter 13 Traction Electrification, and Chapter 15, Communications and Control.

19.1.2 References Data

The design will conform to all appropriate applicable standards and codes adopted by the City. Where the requirements of more than one code or standard are applicable, the more restrictive will govern. Designers shall consult the applicable codes and publications, as well as provide mechanical systems in accordance with the most stringent codes and/or industry practices, such as the following:

A. Uniform Plumbing Code

B. Uniform Mechanical Code

C. National Fire Protection Association (NFPA) Standard 130, Fixed Guide Way Transit and Passenger Rail Systems

D. Sheet Metal and Air Conditioning Contractors National Association Inc. (SMACNA) Standards

E. American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) Standards 2005

F. Americans with Disabilities Act

G. International Code Council/American National Standards Institute 117.1

H. Uniform Federal Accessibility Standards

I. U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED®) Rating System for New Construction and Major Renovation Version 2.2 (Sustainability Guide) LEED—NC 2005

For LEED and other requirements see Chapter 26, Sustainability.

19.1.3 Related System Interface

The HVAC and plumbing design shall interface with the design parameters set forth in these criteria for other systems as appropriate. The related system designs can be found in the following chapters:

A. Chapter 3, Environmental Considerations

B. Chapter 6, Civil

C. Chapter 8, Utilities

D. Chapter 10, Architecture

E. Chapter 14, Train Control

F. Chapter 17, Corrosion Control

G. Chapter 18, Yard and Maintenance Facilities

H. Chapter 20, Facilities Electrical

I. Chapter 21, Fire and Intrusion Alarm Systems

J. Chapter 23, Fire/Life Safety

19.2 DESIGN PARAMETERS AND ENVIRONMENTAL CONTROL SYSTEM (ECS)

The environmental control system (ECS) shall control temperature, air velocity, dust, odors, and the direction and spread of smoke during fire emergencies, as prescribed below.

19.2.1 Calculation Requirements—Engineering

The calculations for the engineering phase of the Project should be kept in a mechanical engineering design book. The book should include the following elements: mechanical design criteria, project team contact list, and project schedule, subdivided into plumbing, fire protection, and HVAC (Heating, Ventilating and Air- Conditioning). Each subsection will contain assumptions and calculations, followed by sketches and equipment cut sheets.

19.2.2 Outside Conditions

The outside conditions prescribed herein are for determining the required capacities of HVAC systems. The system equipment shall be suitable for continuous operation (at degraded capacity) during extreme weather conditions. Table 19-1 summarizes these conditions for the City, according to the 2005 ASHRAE Fundamentals Handbook.

19.2.3 Indoor Conditions

Table 19-2 provides the indoor design conditions.

Table 19-1: Design Outdoor Temperature and Wind Conditions

	Temperature			Wind
	Dry-Bulb	Wet-Bulb	Annual Extreme	Wind Speed
Summer (ASHRAE 0.4%)	89° F	73° F	91° F (mean DB)	23 mph
Winter (ASHRAE 99.6%)	61° F	N/A	57° F (mean DB)	23 mph

Table 19-2: Indoor Design Conditions

Building Name	Room Name	No. of Shifts	Design Temperature (°F)	Allowable Sound (DB)	Vent Airflow (CFM)	Pressure +/-	Humidity Control	Alarm Pt (4)
MSF	Parts storeroom		Amb + (1)		20,856	+	No	No
MSF	Parts offices	1	75	-	120	+	No	No
MSF	Tool crib	t	75	-	30	+	No	No
MSF	Corridor	1	75	-	37	+	No	No
MSF	Yard master	1	75	-	20	+	No	No
MSF	Women's restroom	1	75	-		-	No	No
MSF	Men's restroom	1	75	-		-	No	No
MSF	Truck wash	2	Amb + (1)		864	N/A	No	No
MSF	Valve test	2	Amb + (1)		450	N/A	No	No
MSF	Component clean	2	Amb + (1)		900	N/A	No	No
MSF	Test lab	2	Amb + (1)		605	+	No	No
MSF	Building systems	2	Amb + (1)		900	N/A	No	No
MSF	Electronic shop/ Communications shop	1	75	-	140	+	No	Yes
MSF	Rapid transit security	1	75	-	200	+	No	No
MSF	Lobby	1	75	-	0	+	No	No
MSF	Brake shop/HVAC shop/Elec. shop/Air valve shop	2	Amb + (1)		16,724	N/A	No	No

Table 19-2: Indoor Design Conditions (continued)

Building Name	Room Name	No. of Shifts	Design Temperature (°F)	Allowable Sound (DB)	Vent Airflow (CFM)	Pressure +/-	Humidity Control	Alarm Pt (4)
MSF	Wheelset Storage/ Comp chg-out/ Heavy repair	2	Amb + (1)		66,224	N/A	No	No
MSF	S&I tracks	2	Amb + (1)		24,750	N/A	No	No
MSF	Wheel true	2	Amb + (1)		7,160	N/A	No	No
MSF	Foremen offices	1	75	-	320	N/A	No	No
MSF	RR	2	75	-		-	No	No
MSF	RR	2	75	-		-	No	No
MSF	RR	2	75	-		-	No	No
MSF	RR	2	75	-		-	No	No
MSF	Custodial	2	75	-	63	-	No	No
MSF	Battery shop	2	75	-	126	-	No	Yes
MSF	Stair	24-hours	75	-	13	+	No	No
MSF	Stair		75	-	17	+	No	No
MSF	Maintenance offices	1	75	-	300	+	No	No
MSF	Lunchroom (maint.)/vending/kitchen	24-hours	75	-	1,200	-	No	No
MSF	Corridor	24-hours	75	-	59	+	No	No
MSF	Telecom	1	75	-	20	+	No	No
MSF	T/C stor	1	75	-	8	+	No	No
MSF	Custodial	1	75	-	14	-	No	No
MSF	Building system	1	94	-	11	N/A	No	No
MSF	Men's restroom/ locker	24-hours	75	-	677	-	No	No
MSF	Expansion space	1	75	-	40	+	No	No
MSF	Women's restroom	24-hours	75	-	166	-	No	No
MSF	Technical support	1	75	-	220	+	No	No
MSF	Med. office	1	75	-	40	+	No	No
MSF	Exercise	1	75	-	620	-	No	No
MSF	IT/comm. center	24-hours	75	-	40	+	45-55%	Yes
MSF	Supv.	1	75	-	20	+	No	No
MSF	Trng. mgr./Asst. trainer	1	75	-	100	+	No	No
MSF	Storage	1	75	-	10	+	No	No
MSF	Training	1	75	-	1,280	+	No	No

Table 19-2: Indoor Design Conditions (continued)

Building Name	Room Name	No. of Shifts	Design Temperature (°F)	Allowable Sound (DB)	Vent Airflow (CFM)	Pressure +/-	Humidity Control	Alarm Pt (4)
MSF	OCC equip.	24-hours	75	-	120	+	45-55%	Yes
MSF	Operations control center	24-hours	75	-	240	+	45-55%	Yes
MSF	Fire Supp. systems	24-hours	Amb + (1)		8	+	No	No
MSF	Lunchroom (transport)	24-hours	75	-	1,000	-	No	No
MSF	OCC supv.	24-hours	75	-	20	+	No	No
MSF	Yard control tower	24-hours	75	-	160	+	No	Yes
MSF	Transit inspectors	24-hours	75	-	160	+	No	No
MSF	Corridor	24-hours	75	-	59	+	No	No
MSF	Telecomm.	1	75	-	40	+	No	Yes
MSF	T/C stor	1	75	-	8	N/A	No	No
MSF	Custodial	1	-	-	14	-	No	No
MSF	Building systems	1	94	-	11	N/A	No	No
MSF	Archive files (exec./trans)	1	75	-	135	+-	No	No
MSF	Expansion space	1	75	-	140	+	No	No
MSF	Transportation offices	1	75	-	200	+	No	No
MSF	Men's restroom/ locker	1	75	-	166	-	No	No
MSF	Women's restroom/locker	1	75	-	1,134	-	No	No
MSF	Women's restroom	1	75	-		-	No	No
MSF	Men's restroom	1	75	-		+	No	No
MSF	Executive offices	1	75	-	360	+	No	No
MOW	Carpentry shop	24-hours	Amb + (1)		2,883	N/A	No	No
MOW	Fab./Training shop	24-hours	Amb + (1)		1,120	N/A	No	No
MOW	Machine shop	24-hours	Amb + (1)		2,790	N/A	No	No
MOW	Vehicle service bay	24-hours	Amb + (1)		2,232	N/A	No	No
MOW	Building systems	24-hours	Amb + (1)		194	N/A	No	No
MOW	Electronics shop	24-hours	75	-	140	+	No	Yes

Table 19-2: Indoor Design Conditions (continued)

Building Name	Room Name	No. of Shifts	Design Temperature (°F)	Allowable Sound (DB)	Vent Airflow (CFM)	Pressure +/-	Humidity Control	Alarm Pt (4)
MOW	Restroom	24-hours	75	-	182	-	No	No
MOW	Stairs	24-hours	Amb + (1)		23	N/A	No	No
MOW	Signal/comm. shop/Stor	24-hours	Amb + (1)		2,232	N/A	No	No
MOW	Power distr. shop/Stor	24-hours	Amb + (1)		2,232	N/A	No	No
MOW	Structures shop/Stor	24-hours	Amb + (1)		2,232	N/A	No	No
MOW	Track shop/Storage	24-hours	Amb + (1)		2,232	N/A	No	No
MOW	Bldg. & grnds. shop/Stor	24-hours	Amb + (1)		2,325	N/A	No	No
MOW	Corridor	24-hours	Amb + (1)		164	N/A	No	No
MOW	Vehicle equip storage	24-hours	Amb + (1)		6,840	N/A	No	No
MOW	Elevator equip.(3)	24-hours	Amb + (1)		4	-	No	Yes
MOW	Stairs	1	Amb + (1)		29	+	No	No
MOW	MOW office areas	1	75	-	280	+	No	No
MOW	Vending/ Kitchenette	1	75	-	240	-	No	No
MOW	Corridor	1	75	-	57	+	No	No
MOW	Men's lockers	24-hours	75	-	448	-	No	No
MOW	Signal & comm. crew	1	75	-	320	+	No	No
MOW	Power distr. crew	1	75	-	320	+	No	No
MOW	Structures crew	1	75	-	320	+	No	No
MOW	Track crew	1	75	-	320	+	No	No
MOW	Bldg. & grnds. crew	1	75	-	320	+	No	No
MOW	MOW conference	1	75	-	320	+	No	No
MOW	MOW break	1	75	-	240	-	No	No
MOW	Men's restroom	24-hours	75	-	276	-	No	No
MOW	Women's restroom	24-hours	75	-	88	-	No	No
MOW	Women's lockers	24-hours	75	-	97	-	No	No
TW	Wash bay	2	Amb + (1)		12,668	-	No	No
TW	Wash equipment	2	Amb + (1)		5,903	-	No	No

Table 19-2: Indoor Design Conditions (continued)

Building Name	Room Name	No. of Shifts	Design Temperature (°F)	Allowable Sound (DB)	Vent Airflow (CFM)	Pressure +/-	Humidity Control	Alarm Pt (4)
TW	Office	2	75	-	80	+	No	No
TW	Restroom	2	75	-	-	-	No	No
TW	Building systems	2	Amb + (1)		212	-	No	No
Stations	TC&C(5)	1	75	-	-	+	No	Yes
Stations	TC&C battery	1	75	-	-	-(2)	No	Yes
Stations	Elevator equip.(3)	1	85, 94 max		-	-	No	Yes
Stations	Electrical w/UPS	1	80		-	+	No	Yes
Stations	Janitor storage	1	N/A		-	-	No	No
Stations	Trash	1	N/A		-	-	No	No
Stations	Restroom	1	N/A		-	-	No	No
Stations	Ticket vending machine	1	N/A		-	N/A	N/A	N/A
Stations	Manager's booth(6)	1	75	-	-	+	No	No

Notes:
(1) Temperature increase resulting from internal loads effect on ventilated space.
(2) Battery type will dictate the need for ventilation in this space. Manufacturer's specific recommendations will be adhered to as a design criterion.
(3) Elevator equipment room shall have ventilation fan to reject heat as its primary cooling system. If temperature in space rises above 90°F, air conditioning unit shall be energized to maintain a maximum of 94°F. (Packaged cooling should be avoided).
(4) Alarms shall be provided to transit system automation controls system.
(5) Locate all Air-conditioning equipment securely inside the structure or screen from view where mechanical room is not provided.
(6) Air-conditioning unit shall be provided. (Packaged cooling should be avoided).
MSF: Maintenance Storage Facility (Operations Building)
MOW: Maintenance-of-Way Facility
TW: Train Wash Facility
° F: Degree Fahrenheit
DB: Decibel
CFM: Cubic Feet per Minute

19.2.4 Ventilation Rate

The number of air changes per hour (total air circulated) shall be based on the requirements of applicable codes, heating and cooling loads, or odor control (whichever is greater), but shall not be less than four air changes per hour. The ventilation systems shall be designed to provide cross ventilation. The Hawaii Department of Health requires restrooms to be ventilated at a minimum of 4 cubic feet per minute per square foot (cfm/sf). Where not specifically noted elsewhere, ventilation rates shall be in accordance with ANSI/ASHRAE 62.1-2004. Demand-controlled ventilation using carbon dioxide gas detection monitors shall be used where occupant loads vary such as conference rooms, training rooms, lobby, etc. Occupant loads are part of minimum ventilation requirements.

19.2.5 Noise-control Objectives

A proper acoustical environment is as important to human comfort as any of the other environmental factors controlled by ECS. Improper design of ECS equipment can create an unacceptable acoustic environment. The primary objective of ECS acoustical design is to achieve acceptable sound levels for all activities and people involved; this does not necessarily mean the lowest possible sound levels, however. Because of the wide range of activities, appropriate indoor acoustical design levels will vary considerably from room to room and acceptable outdoor levels will depend on local ambient sound conditions. Proper sound levels at various listener locations shall be achieved by controlling the sound generation of the various sources and the sound transmission from the sources to the listeners.

The maximum permissible outdoor sound levels of ECS shall be as prescribed in Chapter 3, Environmental Considerations. Sound control for environmental control systems indoors shall be designed in accordance with the methodologies outlined in the “Sound and Vibration Control” chapter of the *Handbook of Systems and Applications* (ASHRAE), latest edition. The SMACNA Noise and Vibration Manual can be used in lieu of the above.

19.3 SYSTEMS AND EQUIPMENT

Provision shall be made for the installation and removal of each completely factory-built item of equipment. All hatches, hatchways, removable gratings, access plates, and doors intended for use in the installation and removal of mechanical equipment shall be sized, with adequate clearances, so that they can be moved between grade and their location without the need for special disassembly. The installation and removal of equipment from mechanical equipment rooms preferably shall be accommodated by providing adequate access at-grade. Where this is not feasible or economical, the installation and removal of equipment may be accommodated by providing wall or roof openings above or adjacent to the trackway.

Provision shall be made in the form of monorails, lifting hooks, and removable panels for the installation and removal of equipment. Structural openings shall be sized so that each complete factory-built item of equipment can be installed or removed without disassembly or special construction or demolition.

In buildings and stations that are to be constructed in stages under separate contracts, sleeves and block-outs shall be provided in the early stage structures to accommodate fan, piping, and ductwork installation by later-stage contractors. The locations and sizes of the sleeves and block-outs shall be accurately dimensioned to facilitate the subsequent piping and ductwork installation under later-stage contracts and shall be coordinated with other items such as raceways, sprinklers, and lighting fixtures. Pipe sleeves in exterior walls shall be sized to provide sufficient space for watertight sealing around carrier pipes.

All floor-mounted equipment shall be placed on reinforced concrete housekeeping pads at least 4 inches high.

19.3.1 Ventilation Systems—Supply and Exhaust

Exhaust ventilation and make-up air, where required, shall be provided in accordance with Chapter 23, Fire/Life Safety, all applicable codes, Occupational Safety and Health Administration regulations, and NFPA and ASHRAE standards. Dust-collection systems must be installed and maintained in compliance with all applicable codes and the aforementioned regulations and standards.

Supply air units for outdoor air shall be located in a building's systems room and ducted to spaces requiring outdoor air. Exhaust fans shall be roof-mounted in an up-blast or down-blast configuration.

19.3.2 Heating Systems

The spaces will not be heated for personal comfort.

19.3.3 Air-Conditioning Systems and Equipment

19.3.3.1 General

The equipment selection and design of the HVAC shall be done by the designer. However, certain spaces such as the maintenance and repair shops and train wash shall be provided with ventilation-only systems without additional heating or cooling. The maintenance and transportation offices, computer rooms, break rooms, and restrooms associated with the maintenance and safety facility and maintenance-of-way may be air conditioned to meet the requirements listed in the indoor design conditions and shall be provided in accordance with Chapter 23, Fire/Life Safety.

HVAC systems shall prolong the life of equipment through proper control of temperature, ventilation, pressure, and humidity. The use of through-wall air-conditioning units is not acceptable.

19.3.3.2 Computer Room Units

Computer room units serve computer rooms and shall be of either packaged arrangement or split (Condensing Unit and Air-Handling Unit) arrangement. Computer room units shall be capable of providing temperature and humidity control, as well as continuous compressor operation while modulating the cooling capacity of the unit. Computer room units shall be provided with a wall-mounted temperature and humidity microprocessor thermostat. Air-handling units and condensing units shall be provided and connected by insulated refrigerant lines.

19.3.3.2.1 Condensing Unit

The condensing unit shall have an ARI compliant compressor with a suction gas cooled motor, vibration isolators, thermal overloads, internal centrifugal oil pump for forced feed lubrication and an operating speed not greater than 3500 RPM @ 60 Hz. Condensing unit shall be designed for outdoor use with either roof or ground level mounting. The condensing unit shall be of copper or 316 stainless steel for corrosion resistance. Unit shall have inlet and outlet grilles. Compressor shall be of either scroll, reciprocating hermetic type with cooling capacity control, and using at least one digital compressor. The condensing unit shall be constructed of copper tubes in a staggered tube pattern. Tubes shall have high efficiency aluminum plate type fins. Condensing unit shall be furnished with condenser coils, head pressure control, drain pans, fan assembly, refrigerant circuit including liquid and suction refrigerant lines and a sweat adapter kit.

19.3.3.2.2 Air-Handling Unit

The air handling unit section of the computer room unit shall include, but not limited to evaporator coil, fan assembly, electric reheat coil, filter box, cabinet and chassis, and refrigeration circuit, unit disconnect and controls. The refrigeration circuit shall include a liquid line filter drier, expansion valve and quick-connect female coupling on both suction and liquid lines. The unit shall be factory-recharged and sealed. The air- handling section shall be provided with a condensate drain pan, float switch. The fan assembly of the air-handling unit shall comprise of centrifugal type with double width, double inlet, with adjustable belt drive fan motor. The motor shall be capable of operating at 1750 RPM for 60 Hz.

19.3.3.3 Rooftop Air-Conditioning Units

Rooftop air-conditioning units shall be factory assembled and tested; designed for roof installation; and consist of cabinet and frame, supply fan, controls, air filters, refrigerant cooling coil or chilled water cooling coil, compressor, condenser coil, condenser fan, and a factory-mounted disconnect switch. Units shall be direct expansion or chilled water systems. Units shall be mounted on 14 inch-high factory-built roof-mounting curbs. Curb material shall be anodized aluminum or stainless steel.

19.3.3.4 Direct Expansion (DX) Units

All packaged or split air-conditioning units operating on a direct expansion refrigeration cycle shall be provided with refrigerant piping by the manufacturer. The refrigerant piping, fittings, and connections shall be of steel tubing or copper tubing material, or as recommended by the manufacturer of the associated air-conditioning unit. The unit shall be able to function as a single packaged air-conditioning unit without the need for purchase or installation of additional refrigerant components. In general, refrigerant components furnished with packaged air-conditioning units shall include, but are not limited to, evaporator coils, compressor, refrigerant stop valve, check valves, liquid solenoid valves, expansion valves, safety relief valves, hot gas bypass valve (if required), strainers, discharge line oil separator, accumulator, evaporator pressure regulators (direct-acting), filter driers, sight glass and liquid level indicator, gauge glass, moisture indicator, temperature gauges, and pressure and vacuum gauges. All refrigerant components shall conform to ARI (Air-Conditioning and Refrigeration Institute) standards 495, 710, 730, 750, 760.

19.3.3.5 Chillers

The selection of the chiller shall be done to maximize the energy efficiency and the refrigeration capacity of the chiller. The chillers shall have minimum COP (Coefficient of Performance) based on adopted Energy Code (ASHRAE 90.1). All chillers shall be manufactured according to ARI Standard 590.

19.3.3.5.1 Chiller Compressor

The chiller compressor shall be of reciprocating, centrifugal or screw type. Compressor arrangement shall be hermetic or semi-hermetic type. Compressors shall be provided with safety features to protect their motors against high and low temperatures; high and low pressures and abnormal oil-pressure. All motor protection devices shall be NEMA-rated.

19.3.3.5.2 Chiller Condenser

The chiller condenser shall be air-cooled, water-cooled or evaporative-cooled cooled type.

19.3.3.5.3 Chiller Capacity Controls

Cooling capacity control shall be achieved by specifying chillers with multiple compressors, multiple-speed compressors or compressors with cylinder unloading.

19.3.3.5.4 Chiller Safety Controls

Chillers shall be furnished with features to maintain a safe operation. Safety features shall include (but not be limited to) high-condenser-pressure switch, low-refrigerant-pressure switch, oil-pressure control, freeze-protection switch, low-pressure freezestat, flow switch, motor overload protection, power-factor correction capacitors, pressure gauges, indicator lights and compressor cycle meter, ammeter, lock-out timer, alarm-bell contacts, low ambient controls, relief valve, high-motor-temperature protection, high oil temperature controls and unit disconnect switches.

19.3.3.5.5 Chiller Evaporator

Evaporator coolers shall be of the direct-expansion type of which a factory provided thermostatically controlled expansion valve shall meter the flow of refrigerant into the evaporator according to the amount of superheat in the refrigerant vapor leaving the evaporator. The design and manufacture of the evaporator coil and tubes shall conform to ARI standards.

19.3.3.6 Energy Recovery Wheel

All units serving spaces with ventilation requirement shall be provided with an enthalpy energy recovery wheel. A high ventilation requirement shall be defined as such systems that have both a design supply air capacity of 5,000 cfm or greater and have a minimum outside air supply of 70% or greater of the design supply air quantity to that system. Packaged units such as roof top units, air handling units may be provided with factory installed energy recovery wheels. Packaged air-conditioning unit shall be equipped with an optional enthalpy wheel. The energy recovery wheel shall include a rotor (wheel media, hub, spokes and band), shaft and external bearing, drive belt, motor sheave, cassette, brush seal and purge. The media shall have a flame spread of less than 25 and a smoke developed of less than 50 when rated in accordance with ASTM E84. The rotor media shall be coated to prohibit corrosion. The media surface shall be coated with non-migrating solid adsorbent layer. In addition to the desiccant coating that is applied to the surfaces of the substrate, the two faces of the enthalpy recovery wheel shall be covered and sealed with a two-part polymer heavy-duty coating with chemical resistant properties.

19.3.3.6.1 Operation of Energy Recovery Wheel

Energy recovery wheel shall operate by drawing outside air across half of the enthalpy wheel while drawing space exhaust air across the other half. During winter mode, the energy recovery wheel shall be capable of transferring latent and sensible heat from the hotter and moister exhaust air to the colder and dryer outside air. In summer mode, latent heat and sensible heat are transferred from the hotter and moister outside air to the cooler and dryer space exhaust air. Energy recovery with a recovery effectiveness of 50% or greater shall be selected. Fifty percent energy recovery effectiveness is defined as a change in the enthalpy of the outside air supply equal to 50% of the difference between the outside air and space return air at design conditions. The design and manufacture of energy recovery wheels shall be in accordance to ARI Standards 1060-2005, NFPA 90A, NFPA 90B and shall be tested under UL Standard 723.

19.3.3.6.2 Energy Recovery Wheel Control

Air-conditioning unit shall be provided with controls to modulate the reclaim capacity of the wheel and control the temperature and dehumidification produced by the associated energy recovery wheel. Energy recovery wheel shall include, but not be limited to starting and stopping of the exhaust fan, starting and stopping of the enthalpy wheel, controlling the speed of the enthalpy wheel and opening and closing the bypass dampers to the wheel. The outside air dampers shall be controlled either by fully opening or closing, or by modulating depending on ventilation requirement and normal sequence of operation of packaged unit system

19.3.3.7 Reheat Coils

Reheat coils shall maintain the supply air temperature of the space. The reheat coils shall be sized to increase the primary air temperature from the supply air temperature of the central air-handling unit to the room temperature. The reheat coil shall not be capable of supplying air at a higher temperature than that the room set point of 75º F. Reheat coils shall provide heating either by means of electric or heating hot water. Both electric and heating hot water reheat coils shall have an air face velocity not exceeding 800 feet per minute. Electric reheat coils shall be selected to operate on 460/3 phase/60 Hz electrical service. They shall be provided with multiple stage or SCR controls (for capacities 5kW or greater) to modulate the heating capacity of the coils. Heating hot water reheat coils shall be selected such that the pressure drop across the coils is minimized. The water pressure drop through the coil shall be 15 feet maximum and the water velocity shall be within 1-6 feet per second. Capacity controls shall be achieved by the control valves on the coils piping.

19.3.3.8 Air-distribution Systems

A. General

All air-distribution duct systems shall be designed based on recommendations and in accordance with information contained in the latest edition of the *ASHRAE Handbook of Fundamentals*. Supply duct sizes shall be selected for an equal pressure drop or static regain method as appropriate. Air distribution ductwork for ancillary area ventilation systems shall be so arranged that air is not exhausted into or obtained from station public occupancy areas. Design velocities shall be selected to provide the required system performance and to minimize pressure loss and energy consumption, air-borne noise generation, draft, and the intake of dust particles.

B. Sheet Metal Ducts

All ductwork shall be metal except for flexible ducts. Exterior sheet metal ducts shall be constructed of stainless steel with airtight joints. 316 stainless steel ductwork shall be used for interior spaces including ejector rooms, sump pump rooms, and other similar rooms that have high moisture content in the air. Galvanized sheet ductwork shall be used for interior conditioned spaces. 316 stainless steel ductwork shall be used for all toilet/locker rooms exhaust ducts. All ducts shall be sufficiently stiffened and supported to avoid sagging and vibration.

In general, the ductwork fabrication shall be in accordance with Low Pressure or Medium Pressure Duct Construction Standards—SMACNA as appropriate.

Sheet metal supply and return-air duct sizes shall be determined in accordance with the requirements prescribed for low-velocity air-distribution systems in the duct design chapter of the latest edition of the *ASHRAE Handbook of Fundamentals*.

C. Pressure Losses

Pressure loss calculations shall be performed in accordance with the *ASHRAE Handbook of Fundamentals*. The static pressure differential across any supply or return air terminals shall not exceed 0.25 inches water gauge when the system is operating at full capacity.

D. Supply Air Registers and Diffusers

Supply air registers and diffusers shall be selected to provide the required throw and spread with the least amount of draft and noise. All registers shall be provided with adjustable and double-deflection louvers and spin taps or opposed-blade adjustment volume dampers. Volume dampers shall be key-operable through the face of the register. All ceiling diffusers shall be the square, rectangular, circular, or linear type. They shall have adjustable throw, opposed-blade adjustable volume dampers, and adjustable air extractors. Close coordination with the architectural and lighting designs is required.

E. Variable Air Volume Terminals

If provided, variable air volume terminals shall be pressure-independent and shall reset air volume as determined by the space thermostat regardless of any changes in system air pressure. Terminals shall be system powered and shall require no more than 1 inch water gauge static pressure regardless of air quantity. The casing shall be of double-shell construction and meet SMACNA standards with sandwiched "foamed-in-place" insulation. Terminals shall be complete with factory-furnished system-powered actuators, controls, and thermostats.

F. Transfer Grilles

Transfer grilles shall have a maximum velocity of 250 feet per minute (fpm) over the gross area.

G. Transfer Louvers

Transfer louvers shall have a maximum velocity of 250 fpm over gross area.

H. Exhaust and Return Air Grilles

Either all exhaust and return air grilles shall be equipped with fixed, non-see-through blades or louvers, or the duct behind them shall be painted matte black. All grilles shall be equipped with opposed-blade, adjustable-volume dampers key-operated through the face. Exhaust and return grilles shall have a capacity based on maximum velocity of 500 fpm over the gross area.

I. Bypass Dampers

Bypass dampers shall have a maximum velocity of approximately 500 fpm over the gross area.

J. Volume Dampers

Adjustable, opposed-blade volume dampers shall be provided for all branch ducts serving multiple outlets. All dampers shall be equipped with locking quadrants with blades sufficiently stiffened at the edges to effectively close off the duct. Under all conditions of operation, they shall be free from vibration.

K. Splitter Dampers

Splitter dampers shall be used in multiple duct fittings for initial balancing in place of individual opposed-blade volume dampers in each branch of the multiple duct fitting. These splitters shall be adjustable through locking quadrants and shall be single-bladed. The blades shall have edges sufficiently stiffened to avoid vibration under all conditions of operation.

L. Fire Dampers

Fire dampers shall be provided in ducts that pass through fire-rated floors, walls, and barriers. All fire dampers shall be Underwriters Laboratories, Inc. (UL) listed.

M. Back Draft and Relief Dampers

Back draft or motorized shutoff dampers shall be used on exhaust fans where more than a single fan discharges into a common exhaust. Weighted relief dampers shall be used in exhaust ducts and openings where a positive pressure is required to be maintained by a forced air supply and relief exhaust. All back draft and relief dampers shall be the multi-bladed gravity type with neoprene cushioning on blade edges.

N. Air Extractors

Air extractors shall be used in branch duct connections and for registers and diffusers where there is inadequate space for installing multi-bladed volume dampers. All air extractors shall be the movable blade, pivoted type.

O. Turning Vanes

All elbows shall have a full centerline radius at least 1.5 times the width of the duct. Where full-radius curves are not feasible, elbows shall be provided with turning vanes. All turning vanes shall be the double radius type.

P. Access Doors

Access doors shall be provided in ducts and plenums to service fans, dampers, fire dampers, turning vanes, coils, filters, etc. Access doors in plenums shall be hinged and furnished with latches operable from both inside and outside, and door edges shall seal against neoprene gaskets to form an airtight enclosure. Duct access doors shall seal against felt or neoprene gaskets and shall be hinged or fastened by toggle tabs or wing nuts. Access doors in insulated ducts and plenums shall be insulated using sheet metal-insulation-sheet metal construction.

Q. Flexible Duct Connectors

Flexible duct connectors shall be used on indoor fan and air-handling units to connect units to ductwork. The length of each joint shall be selected to adequately accommodate both horizontal and vertical deflections of the fan units. The flexible material shall not be less than 4 inches insulation.

The insulation on indoor ductwork shall be composite insulation with a metal jacket or a Kraft facing. The adhesive used to adhere a jacket or facing to the insulation shall meet fire and smoke hazard ratings as tested by the American Society for Testing Materials (ASTM) E84 procedure, the NFPA 255 procedure, and the UL 723 procedure. In addition to meeting these ratings, the adhesive shall not exceed a flame spread of 25, a fuel contribution of 50, and a smoke development of 50. Accessories such as adhesives, mastics, cements, tapes, and cloths for fittings shall be similar component ratings.

R. Insulation

Insulation shall be provided for the following:

1. Air conditioning supply and return ducts
2. Outside air intake ducts subject to condensation
3. Emergency generator exhaust flue

19.4 AIR FILTRATION

Supply air units shall be provided with replaceable (throwaway) media filter sections arranged in banks as appropriate. At rated capacity, the replaceable filter media shall have an efficiency of not less than 80 percent on the National Bureau of Standards Cotterell and Lint Type Test, and shall not have an initial pressure drop greater than 0.20 inch water gauge. Air filter material shall be rated UL Class I.

19.5 VIBRATION ISOLATION

All equipment that produces vibrations shall be isolated from the structure by spring or rubber-in-shear vibration isolators. All piping and ducts attached to rotating and oscillating equipment shall be isolated from such equipment by flexible connections. Inertia blocks shall be provided as required. Vibration control for environmental control systems shall be designed in accordance with the procedures outlined in the sound and vibration control chapter of the *ASHRAE Handbook of Systems and Applications,* latest edition. Seismic anchoring and sway bracing shall be provided for mechanical systems and equipment. Coordinate with requirements in Chapter 9, Structural.

19.6 FIRE PROTECTION

The fire-protection system shall be provided per code and as required by Chapter 23, Fire/Life Safety.

19.7 PIPING AND ACCESSORIES

All pressure-piping systems shall be designed to meet the requirements of the Code of Pressure Piping, American National Standards Institute (ANSI) B.31, (all applicable sections). All pipe fittings, flanges, valves, and accessories shall comply with ANSI B16.9, 22, and 28 (all applicable sections). All piping systems shall be designed and arranged for neat appearance. They shall be properly sloped for drainage and venting, and properly supported, guided, and anchored to provide required flexibility and to maintain the integrity of all systems without any damage or leaks under all operating conditions. Piping shall be accessible and shall not be embedded in a concrete structure unless embedment is unavoidable because of architectural or structural requirements. Embedded piping shall be provided with adequate clean-outs or access points. Piping in public areas of stations shall not be exposed. All valves and accessories shall preferably be arranged in a manner so as to be accessible for operation without the use of chains or additional operating platforms. Where this is not possible, and valves are above 6 feet, they shall be chain-operated. Sleeves and escutcheons shall be provided wherever pipes pass through structures. The requirements for exterior piping beyond 5 feet of the building line are described in Chapter 8, Utilities. Corrosion-control measures shall be provided in accordance with the requirements prescribed in Chapter 17, Corrosion Control. All exposed piping should be painted according to pipe and jacket insulation painting specifications.

19.7.1 Hydronic Piping

Piping systems for chilled water and heating of hot water shall be designed within a velocity range of 4-10 ft/s to maintain a minimum pressure drop through the pumping system. Pipe pressure drop shall not exceed 4 feet of head per 100 feet of run through heating water or chilled water pipes. Piping systems for drain lines shall be designed within a velocity range of 4-7 ft/s to allow drainage by gravity within permissible drainage slopes.

19.7.2 Heat Transfer Equipment Piping

Heating hot water or chilled water piping serving coils of heat transfer shall be designed to maintain a minimum pressure drop for the pumping system. The water velocity at coil shall be between 1 ft/s and 6 ft/s. Care should be taken to maintain turbulent flow through coils by not reducing the flow below the minimum allowable for the system.

19.7.3 Pipe Unions or Flanges

To facilitate easy removal for servicing, unions or flanges shall be provided on both the inlets and outlets of all apparatus, isolation valves, control valves, and accessories. Wherever two pipes made of dissimilar metals are connected, a dielectric union shall be used to isolate the two pipes from each other, and as required to provide cathodic protection.

19.7.4 Valves

Isolation valves shall be provided on both sides of water heaters, on each pressure main, on each branch of distribution mains, at each plumbing fixture (except where several units are installed in a battery, for which one isolation valve is adequate), on both sides of inline accessories, and on both sides of equipment that requires removal or isolation from pressure for maintenance such as chillers, cooling towers, pumps, heating coils, and control valves. The installation of all valves shall be designed to provide a neat appearance as well as easy grouping with all parts accessible for operation and maintenance. Valve stems shall be horizontal wherever possible. All valves for water and compressed air shall be made of bronze, with screwed ends for up to 2-inch sizes, and iron body, bronze mounted with flanged ends for up to 2-1/2 inches and larger sizes. Valves shall be tagged and charted.

19.7.5 Piping Accessories

All required piping accessories shall be of sufficient size and provided to ensure trouble-free balancing, control, access, and operation of all piping systems.

These accessories shall include, but not be limited to, strainers, vent cocks, dirt and drip legs with drain and flush connection, liquid flow indicators, vacuum breakers, backwater valves, backflow preventers, pressure-reducing valves, shock absorbers and water-hammer arresters, drain and drip legs for gas and compressed air systems, moisture traps for compressed air systems, balancing cocks, relief valves, isolation valves, and pressure and temperature gauges. All piping accessories requiring maintenance or replacement of parts shall be located in accessible places. All dials of gauges and indicators shall be of English or English/International System of Units measurement and shall be of sufficient size and arrangement to be easily seen and read from operating floor levels.

19.7.6 Pipe Expansion Joints

The use of pipe expansion joints shall be avoided wherever possible. Pipe systems shall be arranged to have sufficient offsets and expansion loops to accommodate thermal expansion and vibration. Pipe expansion joints may be used only where pipe expansion loops are impractical. Piping expansion joints shall be selected to provide for not less than 150 percent of the calculated traverse movements. All such expansion joints shall be of stainless steel or monel metal. They shall be the double-compensating type with an anchor in the middle. These shall be guided on both sides in strict accordance with the manufacturer's recommendation. All expansion joints shall be flanged to facilitate easy and quick replacement.

19.7.7 Pipe and Fittings

All station track drainage and subsurface line track drainage pipes and all waste and soil pipes shall be service-weight cast-iron pipe with no hub fittings. Soil pipe from fixtures shall have a slope of 0.25 inch per foot (2 percent slope) in the direction of flow, except that soil pipe running the length of the station shall have a slope of 0.125 inch per foot (1 percent slope) in the direction of flow. Pipes 3 inches in diameter or less shall be installed at a slope of 0.25 inch per foot (2 percent slope).

Vent pipes shall be service-weight cast iron pipe with bell and spigot fittings or hubless, properly pitched, and shall exit the structure.

Cold-water piping embedded in structures shall be hard-drawn copper tubing type “K,” all other hot- and cold-water piping shall be hard-drawn copper tubing type “L” with wrought brass or copper fittings. Copper tubing type “K” and “L” shall be as per ASTM B88.

Force mains shall be of ductile iron pipe with joints of a type approved by the local authority having jurisdiction.

Water service piping shall be ductile iron with dual mechanical-joint type for pipe 2 inches and above, and type “K” copper with wrought fittings for pipe sizes less than 2 inches.

Hose bibs shall be provided with an integral vacuum breaker. Hose bibs in public areas shall be installed in recessed boxes that are operated with keys. The location of hose bibs shall be coordinated with the architectural requirements.

The minimum diameter of waste pipe installed underground or embedded in structural slabs shall be 4 inches.

Dielectric couplings shall be provided for the connection of pipes of dissimilar metals and in all metallic piping entering a facility.

19.7.8 Flexible Pipe Connectors

The use of flexible pipe connectors to connect piping to heating and cooling apparatus shall be restricted to cases where providing piping offsets for flexibility is impractical. Where flexible pipe connectors are used, such as on resiliently mounted air-handling units and pumps, these flexible pipe connectors shall be of stainless steel or monel construction with flanged ends for quick and easy dismantling from pipe systems. They shall be of sufficient length to provide an overall stiffness less than the resilient mounts used for supporting the apparatus.

19.7.9 Pipe Supports, Hangers, Guides, and Anchors

Pipe supports, hangers, guides, and anchors shall be designed to ensure proper alignment of all pipes for operating conditions. The forces caused by the motion of the fluid; the weight of the fluid, piping, valves, and insulation; and thermal expansion/contraction shall be considered as appropriate. All hangers and supports shall be so arranged as to prevent the transmission of vibration from the piping to the structure. Anchors and guides shall be designed to allow pipes to expand and contract without a build-up of excessive stress. Pipe rollers shall be used with all hangers where pipe movement due to expansion or contraction exceeds 0.5 inch. Spring hangers of constant or variable load types, as the case requires, shall be used when piping is connected to vibrating equipment and where supporting vertical pipes.

19.7.10 Insulation

Composite insulation with a metal jacket or Kraft facing shall be used on indoor piping as appropriate. The adhesive used to adhere the jacket or facing to the insulation shall meet the fire and smoke hazard ratings as tested by procedures ASTM E84, NFPA 255, and UL 723. In addition, this adhesive shall not exceed a flame spread of 25, a fuel contribution of 50, and a smoke development of 50. Accessories such as adhesives, mastics, cements, tapes, and cloths for fittings shall have similar component ratings.

Insulation for chilled water supply and return piping and cooling tower condenser return (to water chiller) piping shall be two-piece, heavy density, sectional insulation jacketed with an embossed vapor barrier laminate. Insulation for refrigeration suction piping shall be a 2-inch-thick (minimum) slip-on-type pre-molded cellular glass. Hot water piping and portions of drainage and cold water piping subject to sweating shall be insulated.

19.7.11 Pumps

Pumping-system design shall maintain redundancy as much as possible to allow continuous operation of facilities when pumps are serviced.

As conditions dictate, pumps shall be either single- or double-suction. Pumps shall be arranged so that they can be serviced without any removal of the piping system. This shall include any disconnection of piping from the pumps. Pumps shall have the following characteristics:

A. Maximum pump speed: 3,600 rpm

B. Operating efficiency at design flow rate: within 5 percent of maximum efficiency

C. Pump type: non-overloading

19.8 PLUMBING

19.8.1 Water Service

19.8.1.1 Potable Cold Water Systems

The domestic water service connection to each facility shall be sized for the total peak demand and shall be a minimum of 2 inches in diameter. Each service shall have a main shutoff valve and backflow preventer immediately inside the structure wall of the station or building. Remote meter-reading facilities shall be provided for all facilities.

Stations, ventilation shafts, maintenance shops, the train control center, and other buildings having plumbing fixtures shall be served with water mains sized for the total plumbing fixture demand, plus 10 percent for future expansion. Minimum fixture service requirements shall be per Uniform Plumbing Code.

The service requirements of such outlets as cooling tower make-up water, which are likely to impose additional demand, shall be estimated separately and added to the above fixture service requirements to determine the required total service connection capacity.

The water service connection at each facility for fire protection systems shall be separate from that for domestic water systems. Refer to the fire protection systems section of this chapter for further information.

The domestic water service shall be provided with a pressure-reducing valve when city pressure at the lowest point of use inside the structure is higher than 60 pounds per square inch (psi). The pressure-reducing valve shall be generally located on the discharge side of the main shutoff valve immediately inside the building wall except for where a pressure-reducing valve shall be located at the lowest level of distribution. Sizing of the domestic water distribution lines shall be based on maintaining uniform pressure at all plumbing fixtures located at the same level, to minimize shock and water hammer, and to maintain a minimum of 20 psi pressure at each flush valve. All pipe lines shall be run in a systematic manner, parallel and at right angles with walls, and properly pitched for drainage.

Water-hammer arresters shall be provided for long pipe runs and branches with flush valves. In addition to the main shutoff valve, isolation valves shall be provided in branch lines and for each floor level to facilitate maintenance in individual areas without losing service for the entire facility. Pressure-reducing valves and backflow preventers shall be provided where automatic makeup for HVAC equipment is connected to the potable water system.

19.8.1.2 Hot Water Systems

Hot water systems for facilities having lavatories, showers, and service sinks shall include water heaters, circulating hot water pumps where required, hot water distribution piping, and pipe accessories. All hot water pipes serving more than a single fixture shall be sized for the simultaneous fixture demand. All pipes shall be arranged in an orderly manner and provisions made for thermal expansion and drainage. All hot water pipes shall be insulated. Isolation valves shall be provided for all branches to facilitate maintenance.

19.8.2 Plumbing Fixtures

19.8.2.1 General

Location and type of plumbing fixtures shall be fully coordinated with the architectural requirements.

19.8.2.2 Fixtures

Water closets shall be wall-hung, of the siphon-jet, elongated-bowl type, and provided with a flush valve. Urinals shall be wall-hung, of the siphon-jet type, and provided with a flush valve. Lavatories shall be wall-hung. All wall-hung fixtures shall be supported by standard chair supports. Service sinks shall be of stainless steel or monolithic precast terrazzo equipped with a stainless steel rim guard.

Water closets in passenger stations will be floor-mounted and bottom-discharged.

Water-coolers shall be wall-mounted, and shall have a bubbler of vandal-resistant design.

The service sink in the battery room shall be acid-resistant and supplied with a wall hanger, rim-guard, and standard trap.

Showers shall have private compartments complete with partitions, receptors, curtain rails, and curtains. The fountain shall be of precast terrazzo, circular or semi-circular and foot-operated (or infrared unless otherwise specified) with supplies from below, and shall have a vent-off drain and powdered soap dispenser with chrome finish hardware

19.8.2.3 Fixtures for Persons with Disabilities

Stations and other facilities having more than one water closet will accommodate each gender including but not limited to persons with disabilities. In stations and other facilities having only one water closet, plumbing fixtures shall be installed to accommodate persons with disabilities in accordance with ANSI 17.1 and the applicable provisions of the Hawaii Uniform Building Code.

19.8.2.4 Hose Bibs and Concealed Hydrants

Hose bibs shall be provided in rooms where there are water closets and trash rooms; battery rooms; near the elevator and escalator pits; in aerial and at-grade stations platforms; at station entrances; and in the concourse areas of stations and other areas where periodic cleaning is required. For station platform areas, a 3/4-inch concealed hydrant as close as practicable to the center of each platform, and additional hydrants or hose bibs as required, shall be provided so that any point of the platform (excluding the trackway) is not more than 75 feet away. All hydrants inside buildings and stations with side platforms shall be installed in walls in stainless steel or nickel bronze boxes with flanges flush with the wall. Exterior hose bibs shall be installed in exterior walls in nickel bronze boxes flush with the wall. Hydrants for stations with center platforms shall be of the nickel bronze box type and shall be installed in platforms flush with the finished floor. All exterior hose bibs and hydrants in unheated areas shall be a loose key type. Hose bibs in battery rooms shall have an acid-resistant finish.

19.8.2.5 Water Supply

All water supplies to fixtures in public areas shall have key-operated service valves. Water supply to lavatories and flush-valve fixtures shall have water-shock absorbing provisions. Vacuum breakers shall be provided on all outlets with hose bib connections and submerged inlets.

19.8.2.6 Plumbing Fixture Connections

All services and piping connections for plumbing fixtures shall be selected for the pressure as recommended by the fixture manufacturer but not less than 25 psi for flush valves and not less than code-permitted pressure for other fixtures (Table 19-3 and Table 19-4).

Table 19-3: Fixture Unit Demand

Fixture	Demand
Water closet, flush valve	1.6 gpf
Urinal, flush valve	1/8 gpf
Lavatory	2 gpm
Service sink	2-3 gpm
Drinking fountain	0.5 gpm
Shower	2-2.5 gpm
Hose bibb	2.5 fixture units + continuous demand outlet of 5 gpm
Sink (wash-up, each set of faucets)	2-2.2 gpm
Sink (wash-up, circular spray)	2.5 gpm

gpf = gallons per flush
gpm = gallons per minute

Table 19-4: Services and Piping Connections for Plumbing Fixtures

Fixture	Fixture Symbol Remarks	Soil or Waste (inches)	Trap Size (inches)	Vent Pipe (inches)	HW Pipe (inches)	CW Pipe (inches)
Water closet	P-1 wall mounted	3	Integral	2	No	1
Urinal	P-2 wall mounted	2	1-1/2	1-1/2	No	3/4
Lavatory	P-3 wall mounted	1-1/2	1-1/2	1-1/2	1/2	1/2
Mop service basin	P-4 floor mounted	3	3	1-1/2	1/2	1/2
Drinking fountain	P-5 wall mounted	1-1/2	1-1/2	1-1/2	No	1/2
Hose bibb	HB flush with walls	No	No	No	No	3/4
Floor drain	FD flush with floors	3	3	1-1/2(min)	No	*
Eye wash/Body shower	P-6	3**	No	No	No	1-1/4

**Trap primers shall be provided where judged to be necessary and as required by local codes.*

*** Drain may not be required by all jurisdictions.*

19.8.3 Domestic Water Heaters

Domestic water heaters shall be electric water heaters regardless of capacity. Water heaters shall be properly sized for the plumbing fixture demand. Hot water in remote locations of a building may require a hot water return pump for circulation unless water is delivered in 15 seconds and unless otherwise specified. The operation of the hot water return pump shall be controlled with an aqua-stat or balancing valves located in the hot water return piping, before the water heater. Restrooms in remote locations may use instantaneous water heaters for tempering water.

19.8.4 Drains

All floor, area, and roof drains shall be of the bottom-outlet type wherever possible. Where space is not adequate to use bottom outlet drains, drains with side outlets may be substituted. All drains used in membrane waterproof floors and roofs shall be provided with flashing collars securely clamped to the waterproof membranes or flashing. Floor drains in public areas shall be nickel-bronze or stainless steel finish. Finish is to be determined by floor material, which must be coordinated with the architectural requirements. Floor drains in public spaces shall be installed with vandal-resistant screws. Area drains shall be ductile iron unless otherwise specified.

All drainage from HVAC systems shall be removed through waste drains only.

No mechanical equipment drains shall be connected directly into any drain system. Indirect drain connectors with an air gap shall be used.

19.8.4.1 Floor Drains

Floor drains shall be provided at building and station entrances, underneath walk-off mats near entrances, in emergency exit stairwell trash rooms, and custodial rooms, all unassigned rooms in stations, and as required to accommodate condensate draining. Drainage provisions at station main entrances, building entrances, and approach areas of elevators and escalators at grade level shall be of a trench-drain type.

Escalator and elevator pits shall have small sumps for pumping out accumulated water by means of an oil-minder sump pump. Water closet rooms containing two or more water closets or a combination of one water closet and one urinal shall be equipped with a floor drain.

Trap primers shall be as provided by local codes and where floor drains are not easily accessible and as required by local codes. Floor drains may be provided immediately beneath all hose bibs inside buildings and stations. Station platforms that have a slope toward the trackway of at least 1 percent do not require floor drains beneath the hose bibs. Platforms with a lesser slope shall be provided with a floor drain immediately beneath each hose bib.

19.8.4.2 Area Drains

Area drains shall be provided at station and building entrance areas, emergency exits, exterior elevators, and escalators.

19.8.4.3 Roof Drains

Roof-drainage systems shall be designed to handle the rainfall intensity for 100-year frequency.

Roof drains shall be of cast iron or other approved corrosion-resistant material. Roof drains passing through the roof into the interior of a building shall be made watertight at the roof line by the use of a suitable flashing material. Refer to Chapter 10, Architecture, for details.

Roof drains shall be equipped with strainers extending not less than 4 inches above the roof surface. Drains shall have a minimum inlet area 1-1/2 times the area of the pipe to which they are connected.

Strainers for roof-deck drains for use on parking decks and similar occupied areas may be of an approved flat-surface type that will be lower than the deck. Such drains shall have an inlet area not less than 2 times the area of the pipe to which they are connected. The strainers shall be suitable for H-20 traffic load.

19.8.5 Traps

All traps shall be of plain pattern having a seal of not less than 2-1/2 inches and not greater than 4 inches. All traps shall be of the same size as that for the piping system to which they are connected. All exposed traps in water closet rooms shall have a chrome finish with stop and traps encased per ANSI 17.1. All floor drains connected to the sanitary sewer system shall be provided with a trap.

19.8.6 Clean-Outs

Clean outs shall be provided on all soil, waste, and drain lines for each pair of 45-degree bends, for each 90-degree bend, and for each 100 feet of straight run or some fraction thereof. All clean-outs brought to finished floors shall terminate with removable clean-out brass or nickel bronze covers at paved tile floors, or stainless steel covers on concrete floors, flushed with the floor. Clean-outs shall be of the same size as the size of pipes served for pipes 4 inches and smaller; 4 inches for pipe sized 4 inches to 6 inches, and 6 inches for pipe sized larger than 6 inches. No floor clean-outs in public areas shall be provided. Floor clean-outs from public areas may be extended to non-public areas.

19.8.7 Soil and Waste Systems

The soil and waste system for facilities shall include soil and waste piping from all plumbing fixtures and floor drains, sewage ejector stations, and ejector discharge piping for stations. All soil and waste pipes shall be sized for fixture demand and as required by applicable plumbing codes and ordinances.

19.8.8 Vent Systems

Vents shall be provided for all soil and waste systems and sized in compliance with applicable plumbing codes and regulations. All horizontal vent pipes shall be kept as short as possible, pitched at 1/4 inch per foot toward soil and waste pipes, then rise to the outside in the most direct way. Each vent riser shall be properly flashed at roof penetration.

19.8.9 Sewage-ejection Systems

19.8.9.1 General

Due consideration shall be given to performance, noise, durability, standardization, and handling characteristics when selecting equipment for the sewage-ejection systems. All equipment selected for the sewage-ejection systems shall be manufacturer's standard products suitable for competitive bidding. For corrosion-control requirements, refer to the Chapter 17, Corrosion Control.

19.8.9.2 Ejector Stations

Subsurface facilities having water closets shall be provided with sewage-ejector stations. Sewage-ejector stations shall be of electric duplex vertical centrifugal wet pit sum pumps. These sections should be modified to eliminate pneumatic ejector units.

19.8.10 Grease, Oil, and Sand Interceptors

Grease, oil, and sand interceptors shall be provided as required by code and environmental standards for effluent to public waters. Interceptors shall conform to all local codes that govern the installation.

Floor-drainage systems serving maintenance shops and vehicle storage areas shall be provided with oil and grease separators, as well as sand traps for extraction of oil, grease, sand, and other substances that are harmful or hazardous to the structure or to the public drainage system. Separators and traps shall have sufficient capacity to retain all sludge between cleanings.

19.8.11 Sanitary Facilities

All drains from mop sinks, lavatories, water closets, and other miscellaneous drains/sanitary waste shall be run by gravity where feasible to existing public sanitary sewers. If a gravity run cannot be accomplished, drains/sanitary waste lines shall be run to sewage-ejector pits equipped with duplex ejector pumps or a sump equipped with non-clog duplex vertical centrifugal wet pit sump pumps. The discharge shall then be pumped to the nearest public sanitary sewer line(s). For corrosion-control requirements, refer to the Chapter 17, Corrosion Control.

19.9 COMPRESSED AIR SYSTEM

19.9.1 General

Provide a complete and functional system to deliver compressed air to the points of use for the maintenance shops and yards. The design, materials, fabrication, assembly, erection, installation, and examination, inspection, and testing of compressed air systems shall be in conformance with ASME B31.9 and SMACNA Seismic Restraint Materials. Piping and fittings used for compressed air systems shall include copper, stainless steel, and carbon steel. The air compressors, dryers, and other major compressed air-generation equipment shall be located in the building systems.

19.9.2 Compressed Air System Accessories

Provide a complete compressed air system that includes, but is not limited to, air compressors, air dryers, air receivers, desiccant air dyers, desiccant, piping and fittings, pressure gauges, hangers and supports, quick disconnect couplings, filters, strainers, traps, lubricators, flexible connections, dielectric unions, hose reel assembly, valve box, identification labels for piping, and tubing. Air compressors shall be factory-provided with after-cooler such that the discharge temperature into the compressed air piping does not exceed 100ºF.

19.9.3 Compressor

The air compressor shall be a, single acting or double acting reciprocating or rotary vane screw compressor. The air compressor shall either be of air cooled or water cooled type. The air compressors shall be of 460 volts/3 phase/60 hertz electrical service.

19.9.4 Dryer

The air dryer provided for the compressed air system shall be of the heatless type with a working pressure of 125 pounds per square inch. Dryer shall conform to ASME BPVC SEC VIII D1 with flanged or threaded fittings and drain valve. Desiccant shall not cake or nest.

19.9.5 Compressed Air Piping

Compressed air systems with pipe sizes equal to or less than 2-inch diameter shall use copper material with threaded pipe and fittings connections. Copper tubing shall be type K or L, hard drawn, Class 1 and shall conform to ASTM B 88. Compressed air systems with pipe equal to or greater than 4-inch diameter shall use carbon steel or stainless steel material with flanged pipe and fittings connections.

19.9.6 Noise

The compressor unit selected shall generate a maximum allowable sound level in the surrounding area as recommended per the noise control objectives of this chapter.

19.10 ENERGY CONSERVATION AND MANAGEMENT SYSTEM

A centralized Energy Management System (EMS) shall be a web-based system that addresses the following criteria:

A. Ability to conform to peak-load criteria for energy cost savings

B. Automated equipment maintenance scheduling resulting in lower anticipated equipment life-cycle costs

C. Benefits of monitoring equipment performance to be within acceptable limits

D. Utility usage patterns

E. Temperature setbacks corresponding to occupancy and utilization patterns

F. Uniform and limited control of temperature settings

G. Filter performance monitoring and replacement pattern data accumulation

H. Ability to monitor and record indoor and outdoor conditions affecting HVAC systems, as well as alarms, failures, and abnormal operating conditions

I. Ability to automatically control selected equipment such as chillers, air handlers, pumps, fans, valves, and automated dampers, as well as lighting in selected areas

J. Ability to perform energy accounting by displaying and recording electrical and natural gas flows.

The EMS input/output hardware shall be capable of receiving and sending both digital and analog signals. All functions of the EMS shall be monitored by means of color-coded graphic displays on monitors. The EMS operating environment shall be similar to “MS Windows.” Passive energy consumption reduction strategies, such as increased insulation and isolation or temperature controlled and ambient spaces and increased equipment capacities to reduce duty cycles, shall be used. The EMS system is to be controllable from remote locations and terminals.

END OF CHAPTER

Honolulu High-Capacity Transit Corridor Project

(Project)

DESIGN CRITERIA

CHAPTER 20

FACILITIES ELECTRICAL

May 22, 2009

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20.0 FACILITIES ELECTRICAL

20.1 GENERAL

20.1.1 Introduction

This chapter defines the functional and design requirements of the electrical and lighting systems for passenger stations, transit centers, and maintenance facilities of the Honolulu High Capacity Transit Corridor Project (Project). Electrical standard requirements, applicable codes, standard specifications, and standard drawings shall be used to supplement these criteria.

These criteria have been established to provide the basis to accomplish design efforts involving facilities disciplines. The responsibility for design integrity, as well as integration and coordination with other facilities and rail-systems designers remains with each of the designers.

20.1.2 Goals

Electrical spaces shall be properly located and sized to facilitate the installation and maintenance of equipment. The design of the facilities' electrical systems shall provide for their safe, reliable, and continuous operation. Accessibility shall be provided to permit removal and replacement of major equipment. These criteria are intended to promote uniformity in the design approach and to standardize the type of equipment and its location throughout the system. Additionally, this chapter of the Compendium of Design Criteria:

A. Applies to the entire project's system, which includes the following types of facilities:

1. Maintenance and Storage Facility (MSF)
2. Operations control center (OCC)
3. Passenger stations (stations)
4. Parking structures
5. Transit centers
6. Traction power substations (TPSS). These criteria apply to only low-voltage power and lighting inside TPSS.
7. Guideway lighting and ancillary equipment.

B. Includes the facilities' electrical requirements for, and connections to, the following systems:

1. Electrical utility
2. Telephone utility
3. Cable television utility
4. Electrical distribution

5. Lighting
6. Emergency power
7. Elevators and escalators
8. Fare vending
9. Illuminated signs
10. Grounding systems
11. Lightning protection system
12. Raceway systems
13. Signal and communications rooms
14. Traction power equipment used to provide traction power inside the maintenance and storage building.

20.1.3 Reference Data

The design shall conform to the adopted editions of all appropriate applicable standards and codes adopted by Federal, State, and Local jurisdictions. Where the requirements of more than one code or standard are applicable, the more restrictive shall govern. Applicable standards and codes include the following:

A. National Fire Protection Association (NFPA) 70: National Electrical Code (NEC)

B. National Electrical Safety Code

C. American National Standards Institute (ANSI)

D. Underwriter’s Laboratories (UL)

E. National Electrical Manufacturers Association (NEMA)

F. Americans with Disabilities Act (ADA)

G. Illuminating Engineering Society of North America (IESNA), Lighting Handbook

H. American Society of Heating, Refrigeration and Air Conditioning 90.1 1999 (Hawai‘i Model Energy Code)

I. NFPA 130: Standard for Fixed Guideway Transit and Passenger Rail Systems

J. ASME A17.1: Safety Code for Elevators and Escalators

K. NFPA 780: Standard for the Installation of Lightning Protection Systems

20.1.4 Related System Interface

The facilities' electrical design shall interface with the criteria for the operations; utilities; stations; corrosion control; yard and shops; heating, ventilation, and air conditioning systems (HVAC); communications; fire alarm; intrusion; supervisory control and data acquisition; train control; and elevators and escalators. The related design criteria chapters include the following:

A. Chapter 1, General

B. Chapter 3, Environmental Considerations

C. Chapter 8, Utilities

D. Chapter 9, Structural

E. Chapter 10, Architecture

F. Chapter 13, Traction Electrification

G. Chapter 14, Train Control

H. Chapter 15, Communications and Control

I. Chapter 16, Fare Collection

J. Chapter 17, Corrosion Control

K. Chapter 18, Maintenance and Storage Facility

L. Chapter 19, Facilities Mechanical

M. Chapter 21, Fire and Intrusion Alarm Systems

N. Chapter 22, Elevators and Escalators

O. Chapter 23, Fire/Life Safety

P. Chapter 25, System Safety and Security

Q. Chapter 26, Sustainability

20.2 DESIGN REQUIREMENTS

20.2.1 Design Calculations

Calculations shall be performed and documented in sufficient detail to permit evaluation of the requirements of this chapter. Formulas, inputs to formulas, units, and assumptions shall be documented.

Short-circuit calculations shall be completed for the electrical distribution system based upon the actual short-circuit capacity obtained from the utility at the electric service entrance. If the utility's actual short-circuit capacity is not available, an infinite bus assumption shall be made. Results of calculations shall be placed at switchboards, panelboards, transformer secondaries, enclosed bus duct, and other feeder and branch circuit terminations sized #2 AWG and larger on a single-line drawing of the electrical distribution system.

Coordination studies shall be performed on normal and emergency/essential power distribution systems. Equipment ratings and ground-fault and overcurrent protective devices shall be selected accordingly.

Voltage drop calculations shall be completed for maximum loads, long run circuits and feeders, and under motor starting conditions. Motor circuit calculations shall be based on an 85 percent lagging power factor. Capacitor banks should be considered to improve the power factor.

Lighting-level calculations shall be completed for all interior and exterior spaces.

20.2.2 Basis for Design

20.2.2.1 Utilization Voltages

Electric utilization voltages shall be according to the following:

A. Advertising dioramas: 120 volts, single phase

B. Communications equipment: 120 volts, single phase

C. Convenience outlets: 120 volts, single phase

D. Exit signs: 120 or 277 volts, single phase

E. Emergency power systems: 208/120 or 480/277 volts, three phase

F. Fare vending: 120 volts, single phase

G. Heaters: to 1,500 watts: 120 volts, single phase

H. Heaters: 1,501 to 5,000 watts: 208 volts, single phase

I. Heaters: 5,000 watts and greater480 volts, three phase

J. Lighting, ballasted types: 120 or 277 volts, single phase

K. Motor controls: 120 volts, single phase

L. Motors, 1/2 horsepower and smaller: 120 volts, single phase

M. Motors larger than 1/2 horsepower: 480 volts, three phase

N. Station signing: 120 or 277 volts, single phase

20.2.2.2 Voltage Drop

Branch circuit voltage drop from 480 volt or 208V switchboards to point of utilization shall not exceed 5 percent.

20.2.2.3 Demand Factors

The following demand factors shall be used for selecting switchboard feeder breakers, panel boards, feeders, and transformers:

A. Service: Demand Factor

B. Lighting and signs: 1.0 x connected load

C. Emergency lighting: 1.0 x connected load

D. Communications systems: 1.0 x connected load

E. Escalators: 0.85 x connected load

F. Elevators: 0.50 x connected load

G. HVAC equipment: 0.80 x connected load

H. Fare vending: 0.50 x connected load

I. Drainage pumps and ejectors: 0.50 x connected load

J. Convenience receptacles where load is not defined: 1.5 ampere each

20.2.2.4 Harmonics

Lighting and equipment shall be selected to limit harmonic distortion. Lighting shall have total harmonic distortion of less than 10%. Consider filters and input line reactors for equipment which normally produces harmonics such as variable frequency drives and uninterruptible power supply (UPS).

20.2.2.5 Safety Considerations

Ground fault protection shall be provided on branch circuits that have equipment or outlets for which personnel protection is required by either the NEC or engineering judgment. Ground fault tripping shall be at the UL Class A level (5 milliamperes). Arc flash hazard warning labels shall be provided on all switchboards and panelboards.

Overcurrent elements that: (a) are designed to protect conductors serving emergency equipment motors (fans, dampers, pumps, and so forth), emergency lighting, and communications equipment, and (b) that are located in spaces other than the main distribution system equipment rooms, shall not depend upon thermal properties for operation.

20.3 INCOMING ELECTRIC SERVICE

20.3.1 General

The electrical energy for the facilities' power and lighting systems discussed in this chapter shall be furnished by the Hawaiian Electric Company (HECO). One HECO service shall be provided to each passenger station/transit center facility. One HECO service shall be provided to the yard and shops facility. Service voltage to these facilities will typically be 480/277V, 3-phase, 4-wire.

The preferred method for electrical service delivery to passenger stations shall be that no two adjacent passenger stations are served from the same HECO substation. See Chapter 8, Utilities, for further details.

See Chapter 13, Traction Electrification, for electrical utility service requirements at traction power substations and gap-breaker stations.

20.3.2 Duct Bank

Each incoming primary service duct bank shall extend from the service entrance equipment to a point on the right-of-way to interface with the utility conduits. Design and installation of the duct banks and interface points shall be coordinated through the Project and HECO. See Chapter 8, Utilities, for further details.

20.4 FACILITY POWER SUPPLY

20.4.1 General

Electrical rooms shall include service entrance switchboards, secondary transformers, power distribution and branch-circuit panelboards, motor control centers, lighting control panels, uninterruptible power supply (UPS), and space for adding future equipment.

Ambient environmental conditions for interior electrical equipment to operate at manufacturer's specified conditions shall be provided. Refer to Chapter 19, Facilities Mechanical. Consideration shall be given to locating heat-producing equipment, such as transformers, outside of enclosed rooms.

20.4.2 Electrical Loads

Electrical loads connected to auxiliary power equipment shall be defined as either non-essential or essential.

20.4.2.1 Non-Essential Loads

Non-essential loads are those loads which, if de-energized, would have minor effect on patron safety and none on system safety. This load classification includes all non-essential station loads and part of all station lighting.

20.4.2.2 Essential Loads

Essential loads are those loads which, if lost, would have a detrimental effect on patron and/or system safety. Included are those loads required for the fixed-guideway transit systems to be maintained in the event of a total facility power failure.

20.4.2.3 Future Equipment

Designer shall coordinate with the Architect and other disciplines to include provisions for equipment anticipated to be added in the future, including but not limited to, elevators, escalators, fare gates, and pay telephones. Provisions shall include electrical distribution capacity, space for future circuit breakers, and rough-in conduit to future equipment locations. Rough-in conduit shall be planned and installed in the same fashion as circuits provided in the contract so that when future equipment is installed surface-mounted conduit can be avoided.

20.4.3 Electrical Distribution

20.4.3.1 Power Distribution

Distribution panels shall be located near concentrated loads or in electrical rooms. Loads shall be segregated and connected to separate panels for identified for HVAC, shop equipment, and office. Consideration shall be given to locating heat-producing equipment, outside of enclosed rooms. At passenger stations electrical equipment shall be located inside electrical rooms, or if outside, shall be located so inaccessible to and out of obvious view of the patrons.

20.4.3.2 Ground Fault Protection of Equipment

Ground fault protection shall be provided on the load side of all main and secondary breakers. Ground fault sensing shall provide maximum coordination so that a ground fault shall trip at the first upstream breaker from the fault and not cause tripping of another breaker before a preset time delay.

20.4.3.3 Metering

Customer-owned metering shall be provided. Each main distribution panel and switchboard shall include a metering section consisting of voltmeter, ammeter, kilowatt-hour meter, and demand meter with peak indicator, as well as associated switches, protective fusing, and sensors.

Utility metering shall be provided as required by HECO.

20.4.4 Essential Power Systems

20.4.4.1 Maintenance and Storage Facility Site

A diesel-powered emergency generator shall be provided for the Maintenance and Storage Facility Site. The generator shall supply power to legally required emergency egress lighting. In addition, the generator shall supply power to all loads required to keep the OCC fully operational and occupied. The generator shall be 480/277V output and have automatic startup capabilities upon failure of normal power and re-transfer with adjustable time delays upon restoration of normal power. The fuel tank shall be belly-mounted and sized to supply the rated generator capacity for 72 hours. The generator shall supply the loads below. Demand shall be 100% for the purposes of sizing emergency power systems.

A. Legally required emergency egress lighting for buildings (72-hour requirement for this lighting provides minimal illumination to allow personnel to move about the buildings during extended utility outage.)

B. Internally illuminated exit signs

C. Train storage yard lighting, at 50% illumination

D. Yard train control building

E. Power to elevator cab lights

F. Fire alarm control and management panels

G. Building access control system

H. OCC loads: equipment, workstations, lighting, HVAC for equipment, HVAC for people, and other loads to keep OCC fully operational

I. OCC UPS

The OCC UPS shall supply power to essential loads which cannot tolerate interruption in power during transfer to generator upon utility loss. UPS batteries shall be capable of supplying the rated capacity of the UPS for 2 hours. Coordinate generator and UPS equipment to ensure that UPS does not switch to battery while running on generator power and that generator speed stabilizes quickly without prolonged "hunting" by the speed governor. Provide demonstration under load with actual generator and UPS that verifies that the generator stabilizes within the specified window and that the UPS does not switch to battery.

20.4.4.2 Passenger Stations

The emergency power system for passenger stations shall use two separate UPS systems: one for essential train control and communications (TCC) loads and the other for emergency egress lighting. In addition, a generator receptacle with a manual transfer switch shall be provided to supply power to only the TCC UPS as well as associated TCC HVAC and lighting loads that are necessary to keep the TCC operational. The generator receptacle shall be located on an outside wall accessible for connection to a portable generator.

A. TCC UPS

The TCC UPS shall be capable of delivering a rated load at 208/120 volts, three-phase to TCC branch-circuit panelboard for 208/120 volt single-phase and three-phase loads to meet the requirements for the TCC. UPS batteries shall be capable of supplying rated load for a minimum of 4 hours.

B. Emergency Egress Lighting UPS

The emergency egress lighting UPS shall be capable of delivering a rated load at 480/277 volts, three-phase to the station emergency lighting panel. UPS batteries shall be capable of supplying rated load for a minimum of 90 minutes.

C. Emergency Fluorescent Power Units

Individual fluorescent luminaires with 90-minute power units (battery ballasts) may be provided in non-public areas for the purpose of emergency egress illumination provided that minimum illumination required by contract documents and the Code is maintained along the egress path.

D. Essential Power Loads

The following loads shall be connected to emergency power systems in all passenger stations. Demand shall be 100% for the purposes of sizing emergency power system.

1. Legally required emergency egress lighting for stations and buildings
2. Internally illuminated exit signs

3. Emergency exit stair lights
4. Blue light stations
5. Closed-circuit television cameras
6. Fire alarm control and management panels
7. Intrusion alarm control panels
8. Public address system
9. Communications, computers, and bus-operation equipment in the train control center
10. Power to elevator cab lights
11. Station manager's booth
12. Guideway safety walk lighting for passenger train evacuation

20.5 PANELBOARDS

20.5.1 Placement

Panelboards shall be placed near or central to their loads. They shall be located in electrical rooms, electrical closets, or suitable ancillary rooms and shall be easily accessible to maintenance personnel.

20.5.2 Spare Capacity

Panelboards shall be equipped with a minimum of 20 percent spare circuits and bus capacity to complete a standard-size panelboard.

20.5.3 Service Voltages

Panelboards shall be designated for function and service voltage. Panel designations shall be consistent for all passenger stations (Table 20-1).

Table 20-1: Recommended Passenger Station Panel Designation

Panelboards	Designation
480/277 volts	
Lighting panels	LH1, LH2, LH3, etc.
Distribution panels	DH1, DH2, DH3, etc.
Emergency panels	EH1, EH2, EH3, etc.
208/120 Volts	
Lighting, convenience outlets and miscellaneous power	LL1, LL2, LL3, etc.
Distribution panels	DL1, DL2, DL3, etc.
Emergency panels	EL1, EL2, EL3, etc.

20.6 TRANSFORMERS

Dry-type transformers shall be used for all indoor power transformations. Pad-mount transformers, if used in outdoor applications, may be oil-filled. Oil-filled transformers shall be enclosed within a curbing to contain oil in the event of a rupture.

20.7 MOTORS, STARTERS, AND CONTROLS

Where practical, motor control centers with motor-circuit-protector combination starters shall be provided for 480-volt motors. Individually mounted motor-circuit-protector combination starters may be provided where they can be located in a physically secure area.

20.8 ELECTRICAL DISTRIBUTION REQUIREMENTS

20.8.1 Wires and Cables

Conductors for emergency lighting, communication, etc. shall be protected from physical damage by transit vehicles or other normal transit system operations and from fires in the transit system. This shall be accomplished by suitable embedment or encasement, or by routing the conductors through areas of low fire potential (light hazard).

Wire and Cable installed at stations and guideway shall conform to NFPA 130.

20.8.2 Raceway

Materials manufactured for use as conduits, raceways, ducts, and their surface-finish materials, when installed in stations and guideways, shall conform to NFPA 130, the NEC, NEMA, and ANSI standards and UL. Materials located outdoors shall be corrosion-resistant (see Chapter 17, Corrosion Control). Conduit runs shall be limited to a total of 270 degrees of bends without pull or junction boxes.

20.8.3 Grounding

20.8.3.1 General Grounding Criteria

The NEC and the Institute of Electrical and Electronic Engineers (IEEE) publication 142-2007, *Recommended Practice for Grounding of Industrial and Commercial Power Systems,* contain regulations pertaining to system and equipment grounding applicable to the facilities and equipment to be constructed and installed on the system. The codes are to be considered as the minimum requirement for the protection of life and property and should be carefully reviewed during the course of system design.

20.8.3.2 Hazardous Conditions

The types of hazardous conditions that can develop in a transit electrical system are as follows:

A. Single-phase-to-ground faults

B. Multiple-phase-to-ground faults

C. Arcing faults, which may cause burndown

D. Abnormal hazards, such as:

1. Lightning
2. Switching surges
3. Static
4. Contact with a high-voltage system
5. Line-ground faults
6. Resonant conditions
7. Restriking ground faults
8. Cable fire
9. Large stray currents

20.8.3.3 Protective Measures

The facilities' electrical systems shall be grounded and designed so that a circuit protective device shall remove any faulty circuit from the system regardless of the type of fault. The basic reasons for system grounding are as follows:

A. To limit the potential difference between uninsulated conducting objects in a facility and the ground

B. To isolate faulted equipment and circuits when a fault occurs

C. To limit over-voltages appearing on the system under abnormal and hazardous conditions

20.8.3.4 Normal Operating Conditions

Under normal operating conditions, persons within a passenger station or other areas shall not be exposed to a touch potential of more than 50 volts.

20.8.3.5 Abnormal Conditions

The following measures shall be taken to protect transit passengers and personnel under the abnormal condition of a ground fault:

A. Provide a ground grid under each facility

B. Provide a low-resistance path to ground for ground-fault current

C. Provide means to disconnect the station supply transformer from incoming power in one-half second or less

A design objective of the ground grid is to limit touch potential to 60 volts maximum.

20.8.3.6 Grounding Electrode System

A ground electrode system shall be provided for each facility in accordance with NEC Article 250. The grounding electrode system for passenger stations shall consist of buried ground conductors and electrodes interconnected to form a grid and shall be capable of maintaining a resistance to ground of 2 ohms or less.

20.8.3.7 Facility Ground Grid System

The grounding electrode system shall include a ground grid system. The ground grid shall consist of ground rods and horizontally interconnected longitudinal and lateral bare conductors forming a rectangular grid pattern. The ground grid shall be designed to provide safe step and touch potentials throughout the facility during a maximum available fault current on the electric power system, which shall not exceed the recommended safety limits of IEEE Standard 80. The buried conductors used to form the ground grid shall be bare copper cable interconnected at each crossover point (node) by the exothermic welding process. The ground grid shall be connected to each building steel column by the exothermic welding process. Grids shall be buried in filled trenches or laid on earth and overlaid with at least 18 inches of backfill. Landscaping plans shall be consulted to avoid conflicts with tree roots. Grid locations shall be coordinated with underground utilities and sewer installations to avoid any direct electrical connection to these systems.

20.8.3.8 Grounding Conductor Sizing

Each of the conductors shall be sized so it can safely pass the maximum ground fault current without melting or fusing before the circuit breakers or protective relays disconnect the source of the fault current.

20.8.3.9 Grounding Electrode Conductor

Conductors between the grounding electrode system and the grounded system shall be insulated copper wire or cable in nonmetallic conduit. The conductor shall be sized to preclude fusing under the maximum fault current for that equipment but in no case smaller than permitted by the NEC. Each exposed conductor shall be coated with coal tar epoxy or equivalent waterproof coating to prevent corrosion of the connection.

20.8.3.10 Connection to Utilities

There shall be no connection between the grounding system and any utility (including water) outside the dielectric coupling, which is used to isolate facilities from utilities outside the building line.

20.8.3.11 Grounding Bus Bars

Grounding bus bars for main electrical equipment and communication equipment shall be provided such that no potential equipment location within a facility is more than 30 feet from the nearest bar. The grounding conductor shall be bolted to the bus bar for visible inspection of the connection. Additional grounding conductors shall be provided for major equipment at specified locations. Bus bars shall be connected to the grounding electrode system.

20.8.3.12 Signal Reference Ground Plates

A signal reference ground plate shall be installed in each communication equipment room and signal room. Except for a single point of interconnection to facility grounding electrode system, each signal reference network shall be insulated from other networks and elements of the facility's ground-grid system.

20.8.3.13 Pull Boxes, Manholes, Cable Vaults, and Conduit

All metallic pull boxes, manholes, and cable vaults shall be grounded.

20.8.3.14 Fence Grounding

Fences shall be grounded in accordance with the National Electrical Safety Code and ANSI. Spacing of ground electrodes shall be every 150 feet and on both sides of a gate or other opening in the fence. The fence shall be bonded at gate hinges and other openings to form a continuous path.

20.8.3.15 Metalwork Grounding

All exposed metalwork, such as handrails, stairways, and escalators, shall be bonded to the facility's ground system.

20.8.4 Convenience Receptacles

20.8.4.1 Locations

In public areas convenience receptacles shall be spaced not more than 100 feet apart and may be located flush in a wall or column and be connected to a separate circuit. This circuit shall be energized only for operation by authorized personnel. In non-public areas of stations, receptacles may be surface-mounted and shall be spaced not more than 20 feet apart and shall be supplemented where needed for fixed equipment. In shop and utility spaces of maintenance facilities, receptacles shall be spaced not more than 50 feet apart, not including receptacles required for fixed equipment. In office spaces of maintenance facilities, receptacles shall be spaced not more than 20 feet apart, not including receptacles required for fixed equipment. Receptacles shall be mounted 15 inches above the floor in finished spaces and 48 inches above the floor in unfinished spaces.

20.8.4.2 Hose Bibb Receptacles

A flush-mounted receptacle box with duplex outlet with ground fault protection shall be provided close to the hose bibbs at grade and aerial stations.

20.8.4.3 Circuit Allocation

In public areas, no more than six outlets shall be connected to a branch circuit. In ancillary or service areas, no more than five duplex outlets shall be connected to a branch circuit.

20.8.5 Specific Requirements

20.8.5.1 Equipment/Utility Requirements

Provide complete electrical installation for receptacles, electrical devices and equipment shown on Equipment/Utility Requirements plans. Obtain device and equipment requirements and loads and include in project calculations.

20.8.5.2 Elevators

The power supply to each elevator shall be 480 volt, 3-phase, terminated in a fused disconnect switch in the elevator machine room.

A 208Y/120-volt, 3-phase, 20-amp emergency power service shall be provided for hoistway lighting and receptacles, in accordance with applicable code requirements.

20.8.5.3 Escalators

The power supply for each escalator shall consist of a 480-volt, 3-phase supply terminated in a circuit breaker in the escalator machine space. A 208Y/120-volt, 3-phase, 20-amp service shall be provided for each escalator for maintenance lights, light switch, and receptacle in the machine space. This service is not to be used for emergency power. Escalator control connections to exit signs and roll-down gates shall be provided. Refer to the illuminated sign section below.

20.8.5.4 Electric Automobile Charging

Electric automobile charger systems and outlets shall be provided for employee and public parking areas where included in the project.

20.8.5.5 Fare Vending, Collecting, Gates

Provisions for fare vending, collection and gates shall be provided. The equipment shall be fed from a panelboard located in the electrical room. Provide raceway for future equipment.

20.8.5.6 Illuminated Signs

The number and location of patron direction and information signs and whether internally or indirectly illuminated shall be as shown on architectural general plans and as described in Chapter 10, Architecture. Exit signs for passenger stations shall be provided in accordance with the above reference.

For escalators having no adjacent stairway, associated directional signs shall be interlocked with the escalator controller via an escalator interface terminal cabinet (IFTC) in the escalator machine space.

20.8.5.7 Maintenance Facilities

The installation of electrical wiring, lighting, and power in structures, and the installation of all electrical devices not supplying traction power within all maintenance facilities, shall be in accordance with the NEC, the National Electric Safety Code (ANSI C2), Insulation, Maintenance, and Use of Proprietary Protective Signaling Systems (NFPA 72d), and applicable local codes.

Installation of all electric equipment and wiring used in connection with overhead cranes and hoists shall conform to Article 610 of NFPA 70. To prevent contact with movable maintenance platforms, ladders, or mobile cranes, protected or recessed AC/DC power bus systems shall be provided.

20.9 LIGHTING

20.9.1 Purpose

The lighting criteria contained herein is intended to provide the functional and aesthetic guidelines necessary to design lighting for site areas, passenger stations, trackway sections, transit-related parking facilities, transit centers, TPSS, yards, and shops. Conformance with these criteria is necessary to ensure adequate lighting levels for the system facilities and provide intended quality, convenience, safety, and efficiency for the system.

20.9.2 Design Objectives

A. The objectives for transit facility lighting are to promote safety by identifying and properly illuminating areas and elements of potential hazard. Of special concern are potential tripping hazards, such as at stairs and platform edges where crowding and rapid transfer to and from trains can be anticipated. The lighting system should enhance the system's visual and functional clarity by differentiating between site circulation networks, such as drop-off zones and parking areas, station entrances, escalators, fare vending areas, platforms, maintenance shops, and the storage yard.

B. Coordinate lighting design with the project architect and additional objectives contained in Chapter 10, Architecture.

20.9.3 Design Requirements

The following requirements apply to all facilities:

A. The lighting system shall provide the intended quality and quantity of light for individual areas and be free from glare. Luminaires that emit light above the horizontal plane shall be avoided. Direct light onto nearby windows and illumination onto adjacent properties shall be minimized. Fixture types that minimize light trespass onto adjacent properties shall be used. IESNA TM-11-2000, *Light Trespass: Research, Results, and Recommendations* shall be followed.

B. The lighting system shall be energy-efficient using high-efficiency light sources and auxiliary equipment. Luminaires shall have integral ballasts and fuses unless special considerations dictate otherwise.

C. Lighting equipment shall be vandal-resistant where within reach of patrons or the general public.

D. The lighting system shall be designed to minimize capital and maintenance costs. Special consideration shall be given to ease and cost of maintenance. Luminaire locations shall permit ready accessibility for relamping and periodic cleaning. Consideration shall be given to maintenance access for luminaires placed over escalators or stairwells.

E. Lighting shall be designed to satisfy security requirements and to provide a pleasant environment.

F. Lighting system shall be designed so that the failure of any single luminaire in areas accessible to the public does not leave an area in total darkness.

20.9.4 Standard Equipment

A. Consistency of appearance and lighting levels throughout the system can best be achieved with a high degree of standardization of lighting system components. To the extent possible, luminaires and lamp types shall be standardized system-wide to provide design and perceptual unity and simplify maintenance. A system-wide approach to lighting design shall allow for cost-effective procurement of lamps, luminaires, and auxiliary equipment, as well as standardized installation, repair, maintenance, and replacement.

B. Deviations from standard equipment are allowed only with prior approval.

20.9.5 Lamps

A. Lamps used for illumination of passenger stations and ancillary areas, including parking lots and pedestrian walkways near transit stations, shall be fluorescent, LED or metal halide and have a minimum color rendering index of 80. In areas not generally accessible to transit patrons, such as the maintenance yard, lamps with a lower color rendering index, such as high-pressure sodium, may be employed, but visibility needs should be carefully evaluated. Low pressure sodium is allowed only where specifically indicated on the preliminary engineering and final design drawings.

B. Innovative lighting systems incorporating new technology light sources, such as LED lamps, should be evaluated on a life-cycle cost basis to determine advisability of application for the system.

20.9.6 Lighting Calculation Requirements

A. Lighting shall be designed by the point-by-point method utilizing computer generated calculations. The software used shall be industry recognized and the calculations shall follow IESNA procedures. Calculation results shall and include maximum, minimum, and average illumination levels along with the appropriate uniformity ratios and lighting power densities per ASHRAE 90.1. Calculations shall also include luminaire locations, mounting heights, manufacture catalog data sheet with product selections and options indicated, lamp data sheet, wattage, lumens, color rendering index, color temperature, room surface reflectance values, light loss factors, and photometric file used.

1. Where the following terms are used in reference to lighting levels or calculations, these definitions shall apply:

    a. Minimum (min): the lowest illuminance value of a given set of calculated points.

    b. Maximum (max): the highest illuminance value of a given set of calculated points.

c. Average (ave): the calculated mean value of a given set of calculated points.

d. Ave:min: the numeric ratio of the average divided by the minimum calculated point.

e. Max:min: the numeric ratio of the maximum calculated point divided by the minimum calculated point.

f. Maintained: illuminance values after all light loss factors have been included.

g. Initial: illuminance values before any light loss factors have been included.

h. Minimum maintained average: the lowest allowable calculated average after all light loss factors have been included.

2. Room surface reflectances: obtain reflectance values for actual materials and color used. If reflectances are not available the following shall be used:

a. Interior office spaces: Ceiling 80%, Wall 50%, Floor 20%

b. Interior shop spaces: Ceiling 80%, Wall 30%, Floor 20%

3. Light loss factor (LLF) shall be calculated as follows:

a. LLF = LLD x LDD x BF x Other, as defined below.

i. LLD = Lamp lumen depreciation. This value is based on the assumption that lamp changing occurs in a blanket relamping at 70% of lamp-life. Obtain LLD or maintenance curves from lamp manufacturer. Use LLD at 70% lamp life. If LLD data is not available use the following values:

(a) Linear fluorescent T-8: 90%

(b) Linear fluorescent T-5: 95%

(c) Compact fluorescent: 90%

(d) High Pressure Sodium: 84%

(e) Metal Halide: 68%

(f) Low Pressure Sodium: 65%

(g) Light emitting diode (LED): 80%

ii. LDD = Luminaire Dirt Depreciation. Obtain the luminaire maintenance category from the manufacturer. If not available use the maintenance category from the IESNA Handbook, Figure 9-14 that most closely resembles the particular luminaire. Use Figures 9-15, 9-16, 9-17, or 9-18 to determine the LDD. Assume 3-year cleaning cycle.

iii. BF = Ballast Factor. Obtain the ballast factor for the lamp/ballast combination selected.

iv. Other. Include other factors contributing to the light loss as suited for the application. Consider surface dirt depreciation especially for passenger station canopy if indirect lighting is relied on for the majority of the platform illumination.

20.9.7 Lighting Levels

A. Lighting levels shall define and differentiate between task areas, decision and transition points, and areas of potential hazard. In addition to quantity of light, it is essential that lighting be designed to minimize glare and provide uniform distribution. Luminaires shall be selected, located, and/or aimed to accomplish their primary purpose while producing a minimum of objectionable glare and/or interference with task accuracy, vehicular traffic, and neighboring areas.

B. Lighting levels shall meet the recommendations of the Illuminating Engineering Society of North America, except as specifically noted in

C.

D. Table 20-2. Unless otherwise indicated, a maximum uniformity ratio of 3:1, average-to-minimum, shall be used. The standard references listed in the following tables are provided for assistance with the design effort. In some cases, the required lighting levels listed in the tables exceed those in the referenced standard. Lighting levels should not significantly exceed those provided in Table 20-2, in order to avoid wasting energy by over-lighting.

E. If requirements of the Standard Reference or local ordinances change over time, the Rapid Transit Division shall be notified and a recommendation shall be made.

Table 20-2: Facility Lighting Levels

Facility/Room/Area	Illuminance (fc), Horizontal Minimum Maintained Average, Unless Noted	Standard Reference (IESNA Handbook, 9th Edition, Unless Noted)
Stations/Transit Centers: Interior Locations		
Public stairs	10 ave at 0 feet Ave:min = 2:1	Fig 10-9: Table I-Interior, Service Spaces
Public escalators	10 ave at 0 feet Ave:min = 2:1 use ballustrades	Fig 10-9: Table I-Interior, Service Spaces
Public passenger elevators	10 ave at 0 feet	Fig 10-9: Table I-Interior, Elevators, Passenger
Station manager's booth	15 ave at 2.5 feet provide additional task lighting	Fig 10-9: Table I-Interior, Conference Room, Meeting
Non-public corridors	5 ave at 0 feet	Fig 10-9: Table I-Interior, Service Spaces

Facility/Room/Area	Illuminance (fc), Horizontal Minimum Maintained Average, Unless Noted	Standard Reference (IESNA Handbook, 9th Edition, Unless Noted)
Storage/custodial rooms	10 ave at 2.5 feet	Fig 10-9: Table II-Industrial, Warehouse-Storage, bulky items
Restrooms	5 ave at 0 feet	Fig 10-9: Table I-Interior, Toilets
Elevator equipment rooms	50 ave at 2.5 feet	Fig 10-9: Table II-Industrial, Maintenance
Fire sprinkler valve room	50 ave at 2.5 feet	Fig 10-9: Table II-Industrial, Maintenance
Mechanical, electrical, UPS, battery, train control and communications rooms	50 ave at 2.5 feet	Fig 10-9: Table II-Industrial, Maintenance
Emergency egress paths, electrical, UPS, battery and train control and communications rooms	Initial: 1 ave at 0 feet; 0.1 minimum at any point. After 90 minutes: 0.6 ave at 0 feet; 0.06 min at any point Uniformity Ratio: Max:min = 40:1	IBC, NFPA 101, NFPA 130

Table 20-2: Facility Lighting Levels (continued)

Facility/Room/Area	Illuminance (fc), Horizontal Minimum Maintained Average, Unless Noted	Standard Reference (IESNA Handbook, 9th Edition, Unless Noted)
Stations/Transit Centers: Exterior Locations		
Station platforms, covered	5 ave at 0 feet 5 ave at 5 feet	Fig 10-9: Table V-Transportation, Terminals, Boarding Area
Station platforms, uncovered	5 ave at 0 feet 5 ave at 5 feet	Fig 10-9: Table V-Transportation, Terminals, Boarding Area
Platform edge	10 ave at 0 feet 10 ave at 5 feet Ave:min = 2:1	
Station entrance, pedestrian	5 ave at 0 feet 5 ave at 5 feet	
Station concourse	5 ave at 0 feet 5 ave at 5 feet	
Pedestrian walkways and ramps, within station sites	2 ave at 0 feet 2 ave at 5 feet	
Public stairs	10 ave at 0 feet Ave:min = 2:1	Fig 10-9: Table I-Interior, Service Spaces
Public escalators	10 ave at 0 feet Ave:min = 2:1 use ballustrades	Fig 10-9: Table I-Interior, Service Spaces
Landings at escalators, elevators, stairs	10 ave at 0 feet	
Fare vending, fare collection, gates	15 ave at 2.5 feet	Fig 10-9: Table V-Transportation, Rail Conveyance, Fare Box
Outdoor plazas	to suit local environment	IESNA RP-33-99, §15.0
Vehicular roadway entrance drives	50% greater than connecting public road, compatible with local conditions. Obtain connecting roadway lighting levels by field measurement or from IESNA RP-8-00, Table 2	IESNA RP-20-98, §4.2 for high-volume traffic
Bus-loading zones, off-street	5 ave at 0 feet 5 ave at 5 feet	Fig 10-9: Table V-Transportation, Terminals, Boarding Area
Bike racks/lockers	5 ave at 0 feet 5 ave at 5 feet	
Bus shelters	See City and County of Honolulu standards	City and County of Honolulu standards
Open parking	1 min at 0 feet 0.5 min at 5 feet max:min = 15:1	IESNA RP-20-98, Table 1, §4.1, 4.3, 4.4

Table 20-2: Facility Lighting Levels (continued)

Facility/Room/Area	Illuminance (fc), Horizontal Minimum Maintained Average, Unless Noted	Standard Reference (IESNA Handbook, 9th Edition, Unless Noted)
Kiss-n-ride, pick-up/drop-off	1 min at 0 feet 0.5 min at 5 feet max:min = 15:1	IESNA RP-20-98, Table 1, §4.1, 4.3, 4.4
Emergency egress path	Initial: 1 ave at 0 feet; 0.1 minimum at any point. After 90 minutes: 0.6 ave at 0 feet; 0.06 min at any point Uniformity Ratio: Max:min = 40:1	IBC, NFPA 101, NFPA 130
Covered Parking Structures		
Basic, parking, traffic lane areas	1 min at 0 feet 0.5 min at 5 feet max:min = 10:1	IESNA RP-20-98, Table 2
Ramps (non-parking), day	2 min at 0 feet 1 min at 5 feet max:min=10:1	IESNA RP-20-98, Table 2, Daylight may be considered
Ramps (non-parking), night	1 min at 0 feet 0.5 min at 5 feet max:min = 10:1	IESNA RP-20-98, Table 2
Entrances, day	50 min at 0 feet 25 min at 5 feet max:min = 10:1	IESNA RP-20-98, Table 2, Daylight may be considered
Entrances, night	1 min at 0 feet 0.5 min at 5 feet max:min = 10:1	IESNA RP-20-98, Table 2
Ticket or fare station	15 min at 2.5 feet	
Roof-top parking	1 min at 0 feet 0.5 min at 5 feet max:min = 15:1	IESNA RP-20-98, Table 1, §4.1, 4.3, 4.4
Stairways	2 min at 0 feet 1 min at 5'	IESNA RP-20-98, Table 2
Elevator lobbies	2 min at 0 feet 1 min at 5'	
Public passenger elevators	10 ave at 0 feet	Fig 10-9: Table I-Interior, Elevators, Passenger
Storage/custodial rooms	10 ave at 2.5 feet	Fig 10-9: Table II-Industrial, Warehouse-Storage, Bulky Items

Table 20-2: Facility Lighting Levels (continued)

Facility/Room/Area	Illuminance (fc), Horizontal Minimum Maintained Average, Unless Noted	Standard Reference (IESNA Handbook, 9th Edition, Unless Noted)
Restrooms	5 ave at 0 feet	Fig 10-9, Table I-Interior, Toilets
Mechanical, electrical, communication/control rooms	50 ave at 2.5 feet	Fig 10-9, Table II-Industrial, Maintenance
Emergency egress paths, electrical and communications rooms	Initial: 1 ave at 0 feet; 0.1 minimum at any point. After 90 minutes: 0.6 ave at 0 feet; 0.06 min at any point Uniformity Ratio: Max:min = 40:1	IBC
Maintenance Facilities: Exterior Locations		
Automobile parking	0.2 ave at 0 feet Max:min = 20:1	IESNA RP-20-98, Table 1, Basic
Drives	0.5 ave at 0 feet Ave:min = 6:1	Figure 22-8
Vehicular roadway entrance drives	50% greater than connecting public road, compatible with local conditions. Obtain connecting roadway lighting levels by field measurement or from IESNA RP-8-00, Table 2	IESNA RP-20-98, §4.2 for high-volume traffic
Light trespass beyond property line	0.01 max initial horizontal and vertical at 0 feet at property boundary and beyond. Comply with further requirements in LEED SS-8.	LEED v2.2, Sustainable Site Credit 8: Light Pollution Reduction, Zone LZ1
Train storage area	1 ave at 0 feet Max:min = 8:1	
Train storage area: Emergency lighting between parked trains	50% of normal lighting	
Emergency generator	5 ave at 0 feet	
Chiller	5 ave at 0 feet	
Extensive Cleaning Platform	Task Lighting: 30 ave vertical on face of vehicle	
Maintenance Facilities: Interior Locations		

Table 20-2: Facility Lighting Levels (continued)

Facility/Room/Area	Illuminance (fc), Horizontal Minimum Maintained Average, Unless Noted	Standard Reference (IESNA Handbook, 9th Edition, Unless Noted)
Wheel true track,, machine pit	30 ave at 0 feet	Fig 10-9: Table II-Industrial per Task Type Motor and Equipment Observation
Service and inspection tracks	30 ave at platform height 10 ave at floor below platform 30 ave at bottom of train carriage (pit lighting)	Fig 10-9: Table II-Industrial per Task Type Inspection simple
Component change-out and heavy repair tracks	30 ave at 0 feet	Fig 10-9: Table II-Industrial per Task Type Assembly simple
Truck shop	30 ave at 0 feet	Fig 10-9: Table II-Industrial per Task Type Assembly simple
Tire shop, wheelset storage	30 ave at 0 feet	Fig 10-9: Table II-Industrial per Task Type Assembly simple
Equipment storage, mechanical expansion area	10 ave at 2.5 feet	Fig 10-9: Table II-Industrial, Warehouse-Storage, Bulky Items
Custodial room	10 ave at 2.5 feet	Fig 10-9: Table II-Industrial, Warehouse-Storage, Bulky Items
Car body shop	30 ave at 2.5 feet	Fig 10-9: Table II-Industrial per Task Type Assembly simple
Battery shop	30 ave at 2.5 feet	Fig 10-9: Table II-Industrial per Task Type Inspection simple
Truck wash	30 ave at 2.5 feet	Fig 10-9: Table II-Industrial per Task Type
Component clean/paint	30 ave at 2.5 feet	Fig 10-9: Table II-Industrial per Task Type Inspection simple
Common work area	30 ave at 2.5 feet	Fig 10-9: Table II-Industrial per Task Type Machining rough bench or machine work
Test lab	50 ave at 2.5 feet	Fig 10-9: Table II-Industrial per Task Type Manual crafting, medium
Brake shop	30 ave at 2.5 feet	Fig 10-9: Table II-Industrial per Task Type Machining rough bench or machine work
Air valve repair shop	30 ave at 2.5 feet	Fig 10-9: Table II-Industrial per Task Type Machining rough bench or machine work
Air valve test	50 ave at 2.5 feet	Fig 10-9: Table II-Industrial per Task Type Manual Crafting, medium
Electronics shop	50 ave at 2.5 feet 100 ave at workbench surface (Task lighting)	Fig 10-9: Table II-Industrial per Task Type Machining Medium bench or machine work

Table 20-2: Facility Lighting Levels (continued)

Facility/Room/Area	Illuminance (fc), Horizontal Minimum Maintained Average, Unless Noted	Standard Reference (IESNA Handbook, 9th Edition, Unless Noted)
Electrical shop, mechanical shop	30 ave at 2.5 feet	Fig 10-9: Table II-Industrial per Task Type Machining rough bench or machine work
HVAC shop	30 ave at 2.5 feet 100 ave at workbench surface (Task lighting)	Fig 10-9: Table II-Industrial per Task Type Machining rough bench or machine work
Parts storeroom, component staging	30 ave at 2.5 feet	Fig 10-9: Table II-Industrial per Task Type Warehousing small items
Tool crib	30 ave at 2.5 feet	Fig 10-9: Table II-Industrial per Task Type Warehousing small items
Shipping and receiving	30 ave at 2.5 feet	Fig 10-9: Table II-Industrial per Task Type Shipping and receiving
Loading dock area	10 ave at 0 feet	Fig 10-9: Table II-Industrial per Task Type Materials handling loading
Carpentry shop	30 ave at 2.5 feet	Fig 10-9: Table II-Industrial per Task Type Machining rough bench or machine work
Fabrication shop	30 ave at 2.5 feet	Fig 10-9: Table II-Industrial per Task Type Machining rough bench or machine work
Machine shop, vehicle service bay	30 ave at 2.5 feet	Fig 10-9: Table II-Industrial per Task Type Machining rough bench or machine work
Vehicle equipment storage	30 ave at 2.5 feet	Fig 10-9: Table II-Industrial per Task Type Storage Active small items
Signals and communication shop/storage	30 ave at 2.5 feet	Fig 10-9: Table II-Industrial per Task Type Storage Active small items
Power distribution shop/storage	30 ave at 2.5 feet	Fig 10-9: Table II-Industrial per Task Type Storage Active small items
Structures shop/storage	30 ave at 2.5 feet	Fig 10-9: Table II-Industrial per Task Type Storage Active small items
Track shop/storage, EIC storage	30 ave at 2.5 feet	Fig 10-9: Table II-Industrial per Task Type Storage Active small items
Buildings and grounds shop/storage, yard cleaning storage	10 ave at 2.5 feet	Fig 10-9: Table II-Industrial per Task Type Storage Active bulky items
Building systems	30 ave at 2.5 feet	Fig 10-9: Table II-Industrial per Task Type motor and equipment observation
Train wash bay	10 ave at 0 feet	Fig 10-9: Table II-Industrial per Task Type Wash room
Lobby	10 ave at 2.5 feet	Fig 10-9: Table I-Interior, Office Lobby

Table 20-2: Facility Lighting Levels (continued)

Facility/Room/Area	Illuminance (fc), Horizontal Minimum Maintained Average, Unless Noted	Standard Reference (IESNA Handbook, 9th Edition, Unless Noted)
Operations control center, OCC equipment room,	50 ave at 2.5 feet	Fig 10-9: Table I-Interior, Open Office, Intermittent VDT Use
Open office, rapid transit security, parts offices, tech area, yard control tower, transit inspectors,	50 ave at 2.5 feet	Fig 10-9: Table I-Interior, Open Office, Intermittent VDT Use
Private office, medical office	50 ave at 2.5 feet	Fig 10-9: Table I-Interior, Private Office
Meeting/conference rooms, training room, crew room, OCC viewing area,	30 ave at 2.5 feet	Fig 10-9: Table I-Interior, Conference Room, Meeting
Stairs, corridors, hallways	5 ave at 0 feet	Fig 10-9: Table I-Interior, Service Spaces
Elevators	5 ave 0 feet	Fig 10-9: Table I-Interior, Elevator, Passenger
Storage/janitor rooms	10 ave at 2.5 feet	Fig 10-9: Table II-Industrial, Warehouse-Storage, Bulky Items
Mechanical, electrical, DC, UPS, server, wash equipment, communication, elevator machine rooms, fire suppression system	50 ave at 2.5 feet	Fig 10-9: Table II-Industrial, Maintenance
Restrooms	5 ave at 0 feet	Fig 10-9: Table I-Interior, Toilets
Layover room	30 ave at 2.5 feet	Fig 10-9: Table I-Interior, Reading-Printed tasks
Copy area	10 ave at 2.5 feet	Fig 10-9: Table I-Interior, Offices-Copy rooms
File/reference area	50 ave at 2.5 feet	Fig 10-9: Table I-Interior, Offices-Filing
Kitchenette	30 ave at 2.5 feet	Fig 10-9: Table I-Interior, Food Service Facilities-Pantry
Lunch room, vending machine, break room	10 ave at 2.5 feet	Fig 10-9: Table I-Interior, Food Service Facilities-Dining
Locker area	10 ave at 0 feet	Fig 10-9: Table I-Interior, Locker Room
Exercise room	30 ave at 2.5 feet	Pg. 20-13, Exercise Rooms

Table 20-2: Facility Lighting Levels (continued)

Facility/Room/Area	Illuminance (fc), Horizontal Minimum Maintained Average, Unless Noted	Standard Reference (IESNA Handbook, 9th Edition, Unless Noted)
Emergency egress paths, electrical, UPS, battery and control and communications rooms	Initial: 1 ave at 0 feet; 0.1 minimum at any point. After 90 minutes: 0.6 ave at 0 feet; 0.06 min at any point Uniformity Ratio: Max:min = 40:1	IBC
Traction Power Substation (see Chapter 13, Traction Electrification, for additional requirements)		
TPSS inside	50 ave vertical on face of equipment Ave:min = 3:1	Fig 10-9: Table II-Industrial, Maintenance
TPSS outside	2 min at 0 feet	
Guideway		
Elevated trainway walkway (guideway safety walk)	0.25 min at 0 feet Max:min = 10:1 along length of walkway	NFPA 130-6.2.5. Ambient lighting from other sources shall not be considered in meeting this requirement

20.9.8 Site and Plaza Lighting

Station site lighting includes internal site circulation and access to the station. The placement of luminaires shall not obstruct the movement of vehicles. Luminaire placement shall be coordinated with the landscape and site plan to protect light standards which are located adjacent to roadways, and to ensure that plantings shall not obscure the lighting distribution pattern. Lighting of outdoor plazas, station sites, pedestrian walkways, and similar areas shall be accomplished by using luminaires on low poles mounted on station structures where feasible. In ticket vending machine areas, lighting design shall ensure that glare from luminaires does not obscure visibility of touch-screen displays.

Vehicular access lighting shall provide a natural lead-in to the bus areas and passenger drop-off zones. The illuminance on all access and egress roads shall be graduated up or down to the illuminance level of the adjacent street or highway.

20.9.9 Pedestrian Access Lighting

Pedestrian access lighting shall define pedestrian walkways, crosswalks, ramps, stairs, and bridges. Lighting shall sufficiently define the decision and transition points and areas of potential hazard.

20.9.10 Station Platform and Public Area Lighting

Platform area lighting shall be provided in waiting and loading areas. The lighting elements shall extend the entire length of the platform and shall demarcate the platform and emphasize the platform edge, vertical vehicle surfaces, and landings associated with elevators and stairs. Care shall be taken to avoid blinding train riders with excessive or misdirected lighting or glare. Station lighting shall not cast shadows on roadways below. Station lighting shall not cause glare for motorists on roadways below. Luminaire selection and architectural screening shall be carefully coordinated with the project's architect to address issues of glare and shadow.

Luminaires and lamps to accentuate specific architectural features or artistic works shall be selected by the designer from the standard luminaire/lamp palette or may be custom for the application if approved.

20.9.11 Parking Lot/Garage Lighting

Lighting at surface parking lots and inside parking garages shall meet the recommendations in IESNA RP-20-98, *Lighting for Parking Facilities*. Daylighting shall be considered as a source of illumination inside open parking garages.

20.9.12 Control of Lighting Systems

A. Automatic and manual control arrangements shall ensure efficient use of energy and maintenance procedures. Passenger Station exterior areas shall be artificially illuminated when ambient illuminance drops below 10 foot-candles. During nighttime non-revenue hours, security lighting shall be provided to deter crime and vandalism. (Non-revenue hours shall be considered as the period from 30 minutes after service stops to 30 minutes before service starts). Provision shall be made for photo-control, with time clock and manual override. Ancillary areas shall be individually switched.

B. For energy conservation, the use of daylight harvesting shall be considered for interior office and maintenance spaces that utilize daylighting systems and skylights. Coordinate with the project architect to determine spaces appropriate for daylight harvesting. Where daylighting is used, lighting zones shall be evaluated to determine which areas can be effectively illuminated using daylight, and the lighting control system shall be designed using appropriate photoelectric controls. On/off and automatic dimming systems shall be considered.

C. Guideway safety walk lighting shall be controlled by the OCC with local override at the passenger station from which circuits originate. Guideway lighting shall be normally off during the day and night and used only during train evacuation.

20.9.13 Emergency Lighting

A. Emergency lighting shall consist of appropriately located luminaries, which shall provide adequate lighting for the orderly egress of patrons and employees during power failure. The lighting and wiring system shall meet applicable requirements of NFPA 130, NFPA 101, National Electrical Code, and International Building Code. The luminaries and all exit, egress, and essential directional signage shall be powered by an emergency power source, as described in this chapter.

B. Emergency lighting for stairs shall be designed to emphasize the top and bottom steps or landings.

C. Emergency lighting shall be provided at locations indicated in Table 20-2: Facility Lighting Levels.

D. All exit signs shall be connected to an emergency circuit or be self-illuminating with integral battery pack/charger. Exit signs shall be of the light-emitting diode type, unless otherwise approved.

20.10 COMMUNICATION AND SPECAL SYSTEM SERVICES

Obtain device layouts, cabling, and point-to-point connection diagrams from Core Systems contract. Provide complete rough-in raceway systems, devices boxes and pull-strings for the following systems, including but not limited to:

A. Public Address

B. Local Area Network (LAN)

C. Fare Collection

D. Intrusion

E. Access Control

F. Surveillance Camera

G. Fire Alarm

20.11 CABLE TELEVISION SERVICE

Coordinate with the local utility to provide cable television service to the Maintenance and Storage Facility. Coordinate with the architect to determine outlet locations. Provide conduit and cable for distribution inside and between buildings and to outlets.

20.12 FACILITY MONITOR AND CONTROL REQUIREMENTS

20.12.1 General

These criteria describe the facility requirements and interfacing hardware necessary to enable the OCC to have remote monitor and control capability. The following sections provide the basis for identifying functions that are to be remotely monitored or controlled. Preliminary engineering and final design drawings shall be prepared to show specific information as a guide.

20.12.2 Local Monitor and Control Requirements

Equipment controls, such as fans and pumps, shall be in accordance with NEMA criteria related to the prescribed equipment.

20.12.3 Remote Monitor and Control Requirements

The facility equipment and systems that are remotely monitored and controlled shall have individual circuits extended from their installed locations to the communication room by means of facility-provided conduit, cable, wire, and interface terminal boxes. Where the communications equipment is located in an exterior room, the interface cabinets shall be located in the station adjacent to the entry point of the cables from the communications room.

20.12.4 Interface Terminal Cabinet Wiring

Interface terminal cabinet wiring shall comply with the following:

A. Terminations shall be identified by number and physically positioned on the preliminary engineering and final design drawings.

B. Where monitor or control circuits are to be summarized to reduce monitor points each circuit shall first be terminated on the facility side of the terminal block in the interface terminal cabinet, depending on site-specific conditions. Terminals shall have the capability to be used for multiple circuits.

20.13 LIGHTNING PROTECTION

Lightning protection systems and equipment shall be installed to protect persons, equipment, and facilities against the hazards posed by lightning-related currents and voltages.

A lightning risk assessment shall be performed in accordance with NFPA 780. Lightning protection shall be provided for stations, buildings, and structures that are outside the zone of protection provided by nearby structures and for which the NFPA 780 calculated lightning strike frequency exceeds the tolerable lightning strike frequency.

20.14 SEISMIC REQUIREMENTS

Seismic anchoring and sway bracing shall be provided for electrical distribution systems and equipment. Coordinate with requirements in Chapter 9, Structural.

END OF CHAPTER

Honolulu High-Capacity Transit Corridor Project

(Project)

DESIGN CRITERIA

CHAPTER 21

FIRE AND INTRUSION ALARM SYSTEMS

TO BE DEVELOPED

Honolulu High-Capacity Transit Corridor Project

(Project)

DESIGN CRITERIA

CHAPTER 22

ELEVATORS AND ESCALATORS

TO BE DEVELOPED

Honolulu High Capacity Transit Corridor Project

(Project)

DESIGN CRITERIA

CHAPTER 23

FIRE LIFE SAFETY

May 22, 2009

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23.0 FIRE/LIFE SAFETY

23.1 GENERAL

23.1.1 Introduction

This Chapter establishes the Fire/Life Safety (F/LS) design criteria for the Honolulu High-Capacity Transit Corridor Project (Project). The purpose of this document is outlined as follows:

A. To provide sufficient definition and description of safety characteristics allowing design engineers to select appropriate features for systems equipment and facilities. This document is designed to outline the fire and life safety standards and guidelines to safeguard the life safety of passengers, employees, contractors, emergency responders, and the public, as well as to protect City and County of Honolulu (City) property from fire and other related mishaps; and

B. To define the fire/life safety requirements, which shall be included as part of the contract documents.

Nothing in these criteria is intended to prevent or discourage the use of new methods, materials, or devices, provided that sufficient technical data are submitted and reviewed by the Safety and Security Oversight and Review Committee (SSORC) to demonstrate that the new method, material, or device is equivalent to or superior to the requirements of these criteria with respect to fire/life safety.

The F/LS criteria establish minimum requirements for the following areas:

1. Station Facilities
2. Guideway Facilities
3. Passenger Vehicles
4. Maintenance and Storage Facility
5. Communications
6. Operations Control Center
7. Parking Structure

Transit stations shall pertain to stations accommodating only passengers and employees of the fixed guideway transit systems and incidental occupancies in the stations.

Fire safety on a fixed guideway transit system is achieved through a composite of facility design, operating equipment, hardware, procedures, and software subsystems that are integrated to satisfy requirements for the protection of life and property from the effects of fire. The level of fire safety required for the whole system shall be achieved by integrating the required levels for each subsystem.

These criteria shall apply to all new project rail transit systems and to extensions of the system.

23.1.2 Reference Data

A. Abbreviations

1. ADA Americans with Disabilities Act
2. ADAAG Americans with Disabilities Act Accessibility Guidelines
3. ANSI American National Standards Institute
4. ASME American Society of Mechanical Engineers
5. ASTM American Society for Testing and Materials
6. BLS Blue Light Station
7. CFR Code of Federal Regulations
8. CSS Central Supervising Station
9. EMP Emergency Management Panel
10. E-TEL Emergency Telephone
11. ETS Emergency Trip Switch
12. FACP Fire Alarm Control Panel
13. FDC Fire Department Connection
14. F/LS Fire and Life Safety
15. HFD Honolulu Fire Department
16. HIOSH Hawaii Occupational Safety and Health Division
17. HVAC Heating, Ventilation, and Air Conditioning
18. IBC International Building Code as adopted and administered by the City
19. IEEE Institute of Electrical and Electronics Engineers
20. MOW Maintenance-of-Way
21. MSF Maintenance and Storage Facility
22. NEC National Electrical Code
23. NFPA National Fire Protection Association
24. PA Public Address
25. OCC Operations Control Center

26. SSORC Safety and Security Oversight and Review Committee

27. TPSS Traction Power Substation

28. T-TEL Train Emergency Speakerphone

29. UFC Uniform Fire Code (NFPA 1)

30. VMS Variable-message Sign

B. Definitions

1. Ancillary Area/Ancillary Space: on-public areas or spaces of the stations to house or contain operating, maintenance, or support equipment and functions.

2. Approved: acceptable to the City.

3. Area of Refuge: an area that is either (1) a story in a building where the building is protected throughout by an approved, supervised automatic sprinkler system and has not less than two accessible rooms or spaces separated from each other by smoke-resisting partitions; or (2) a space located in a path of travel leading to a public way that is protected from the effects of fire, either by means of separation from other spaces in the same structure or by virtue of location, thereby permitting a delay in egress travel from any level.

4. At-Grade Station: any at-grade or unroofed station other than an elevated or underground station.

5. Authority: The agency legally established and authorized to construct and operate a fixed guideway transit system.

6. Blue Light Station (BLS): a location along the guideway indicated by a blue light where emergency service or authorized personnel may communicate with the OCC and disconnect traction power by use of an Emergency Trip Switch (ETS).

7. Central Supervising Station (CSS): the principal manned location in the OCC where fire alarm, supervisory, and trouble signals are displayed and where personnel are in attendance at all times to supervise the circuits, monitor signals, and immediately retransmit any signal indicative of a fire to the public fire department communication center.

8. City and County of Honolulu (City): Organization, office, or individual responsible for approving equipment, an installation, or a procedure.

9. Communications: radio, telephone, video, and data services throughout the system, particularly at the central supervising station and command post.

10. Concourse: intermediate level(s) or area(s) connecting a station platform(s) to a public way via stairs, escalators, or corridors.

11. Design Fire Scenario: the approved engineering analysis method, which considers vehicle combustible load, fire transmission between vehicles, and a sequence of events over time to determine the peak heat release rate from a vehicle fire.

12. Elevated Station: a station greater than one story not otherwise defined as an at-grade or underground structure.

13. Elevated Structure: a structure not otherwise defined as a surface or underground structure.

14. Emergency Management Panel (EMP): a location where all necessary on-site control and communication facilities are consolidated for effective response to emergency situations.

15. Emergency Trip Switch (ETS): a device by which traction power may be removed from a designated powered segment by authorized personnel. The device provides local mechanical lockout capability, which precludes restoration of power until the mechanical lockout has been reset. The ETS is an integral part of a BLS.

16. Engineering Analysis (Fire Hazard/Fire Risk Assessment): an analysis that evaluates all various factors that affect the fire safety of the system or component.

17. Fire Emergency: the existence of or threat of fire and/or the development of smoke or fumes that calls for immediate action to correct or alleviate the condition or situation.

18. Fire Protection Rating: the period of time that an opening protective assembly will maintain the ability to confine a fire as determined by tests prescribed in IBC, Section 715. Ratings are stated in hours or minutes.

19. Fire Resistance: the property of materials or their assemblies that prevents or retards the passage of excessive heat, hot gases, or flames under conditions of use.

20. Fire-Resistance Rating: the period of time a structure element, component, or assembly maintains the ability to confine a fire, continues to perform a given structural function, or both, as determined by the tests or the methods based on the tests prescribed in IBC, Section 703.

21. Fire Separation Distance: the distance measured from the building face to one of the following:

    a. The closest interior lot line

    b. To the centerline of a street, an alley, or public way

    c. To an imaginary line between two buildings on the property

    The distance shall be measured at right angles from the face of the wall.

22. Fixed Guideway Transit System (System): an electrified transportation system using a fixed guideway operating on right-of-way for the mass movement of

passengers within a metropolitan area and consisting of its fixed guideways, transit vehicles and other rolling stock, power system, buildings, maintenance facilities, stations, transit vehicle yard, and other stationary and movable apparatus, equipment, appurtenances, and structures.

23. Fixed Guideway Transit Vehicle (Vehicle or Car): an electrically propelled passenger-carrying rail vehicle characterized by high acceleration and braking rates for frequent starts and stops, as well as for fast passenger loading and unloading.

24. Guideway: that portion of the transit line included within right-of-way fences, outside lines of curbs or shoulders, underground tunnels, cut or fill slopes, ditches, channels, waterways, and including all appertaining structures (e.g., traction power substations, communications and signaling buildings, and incoming electrical service buildings).

25. Open Station: a station that is constructed in such a manner that it is open to the atmosphere, such that smoke and heat are allowed to disperse directly into the atmosphere. Roofs or canopies without enclosing walls are not considered an enclosure. Design emphasis shall be for adequate natural smoke dispersal in an emergency.

    For a platform area to be considered “open,” it shall be open to three or more sides. It shall have uniformly distributed openings along the exterior wall that is parallel to the trackway. The area of such openings in exterior walls must be at least 20 percent of the total perimeter wall area.

    The following enclosed areas in open stations are permitted:

    a. Station manager’s booth

    b. Mechanical, electrical, and other spaces typically not used for human occupancy and necessary for the operation of a fixed guideway transit system

    c. Restrooms

26. Operations Control Center (OCC): the operations center where the Authority controls and coordinates the systemwide movement of passengers and trains and maintains communication with its supervisory and operating personnel and with participating agencies when required.

27. Point of Safety: in a transportation system, an enclosed fire exit that leads to a public way or safe location outside the station, trainway, or vehicle, or to an at-grade point beyond any enclosing station, trainway, or vehicle, or another area that affords adequate protection to passengers. For the Project’s open stations, this is the concourse, where the concourse is below the platform, and a public way for open stations without a concourse.

28. Public Way: a street, alley, or other similar parcel of land essentially open to the outside air, deeded, dedicated, or otherwise permanently appropriated to the public for public use and having a clear width and height of not less than 10 feet.

29. Safety and Security Oversight and Review Committee (SSORC): a committee established by the City to facilitate the interchange of information and make evaluations and recommendations for the safety and security of the Project.

30. Standpipe System: an arrangement of piping, valves, hose connections, and allied equipment installed in a building or structure with the hose connections located in such a manner that water can be discharged in streams or spray patterns through attached hose and nozzles for the purpose of extinguishing a fire, thereby protecting a building or structure and its contents in addition to protecting the occupants. This is accomplished by means of connections to water supply systems or by means of pumps, tanks, and other equipment necessary to provide an adequate supply of water to the hose connections.

31. Standpipe Class I System: a Class I standpipe system provides 65-mm (2½-inch) hose connections to supply water for use by fire departments and those trained in handling heavy fire streams.

32. Standpipe System-Wet: a standpipe system having piping containing water at all times.

33. Standpipe System-Manual Wet: a wet standpipe system connected to a water supply for the purpose of maintaining water within the system but does not have a water supply capable of delivering the system demand attached to the system. Manual-wet standpipe systems require water from a fire department pumper (or the like) to be pumped into the system to meet the system demand.

34. Station: a place designated for the purpose of loading and unloading passengers, including patron service areas and ancillary spaces associated with the same structure.

35. Station Platform: the area of a station used primarily for loading and unloading transit vehicle passengers.

36. Surface Structure: any at-grade or unroofed structure other than an elevated or underground structure.

37. System: see “Fixed Guideway Transit System” above,

38. Traction Power Substation (TPSS): a fixed facility within the rail system where electrical equipment is located for the specific purpose of receiving and converting or transforming incoming electrical energy to usable electrical energy.

39. Trainway: that portion of the guideway in which transit vehicles operate.

C. Codes and Standards: F/LS provisions shall be in accordance with NFPA 130, Standard for Fixed Guideway Transit and Passenger Rail Systems, 2007 Edition, as the governing code, and in accordance with the following codes and standards as administered by the City and to the extent used herein. Where more than one adopted/applicable code, standard, or criterion is applicable, the most restrictive shall govern to the extent that it does not conflict with the governing code.

1. 49 CFR Part 37, Transportation Services for Individuals with Disabilities (ADA)
2. ANSI/ITSDF B56.1, Safety Standard for Low Lift and High Lift Trucks
3. ASME A17.1, Safety Code for Elevators and Escalators
4. ASTM E 84, Standard Test Method for Surface Burning Characteristics of Building Materials
5. ASTM E 648, Standard Test Method for Critical Radiant Flux of Floor-Covering Systems Using a Radiant Heat Energy Source
6. ASTM E 1537, Standard Test Method for Fire Testing of Upholstered Furniture
7. International Building Code (IBC)
8. IEEE 383, Standard for Qualifying Class 1E Electric Cables and Field Splices for Nuclear Power Generating Stations
9. Fire Code of the City and County of Honolulu
10. NFPA 1, Uniform Fire Code
11. NFPA 10, Standard for Portable Fire Extinguishers
12. NFPA 13, Standard for the Installation of Sprinkler Systems
13. NFPA 14, Standard for the Installation of Standpipe and Hose Systems
14. NFPA 22, Standard for Water Tanks for Private Fire Protection
15. NFPA 24, Standard for the Installation of Private Fire Service Mains and Their Appurtenances
16. NFPA 25, Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems
17. NFPA 30, Flammable and Combustible Liquids Code
18. NFPA 33, Standard for Spray Application Using Flammable or Combustible Materials
19. NFPA 51B, Standard for Fire Prevention during Welding, Cutting, and Other Hot Work
20. NFPA 58, Liquefied Petroleum Gas Code
21. NFPA 70, National Electrical Code (NEC)
22. NFPA 72, National Fire Alarm Code

23. NFPA 75, Standard for the Protection of Information Technology Equipment
24. NFPA 80, Standard for Fire Doors and Other Opening Protectives
25. NFPA 88A, Standard for Parking Structures
26. NFPA 90A, Installation of Air-Conditioning and Ventilating Systems
27. NFPA 91, Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids
28. NFPA 101, Life Safety Code
29. NFPA 110, Standard for Emergency and Standby Power Systems
30. NFPA 111, Standard on Stored Electrical Energy Emergency and Standby Power Systems
31. NFPA 204, Standard for Smoke and Heat Venting
32. NFPA 220, Standard on Types of Building Construction
33. NFPA 251, Standard Methods of Tests of Fire Resistance of Building Construction and Materials
34. NFPA 255, Standard Method of Test of Surface Burning Characteristics of Building Materials
35. NFPA 256, Standard Methods of Fire Tests of Roof Coverings
36. NFPA 257, Standard on Fire Test for Window and Glass Block Assemblies
37. NFPA 505, Fire Safety Standard for Powered Industrial Trucks including Type Designations, Areas of Use, Conversions, Maintenance, and Operations
38. NFPA 2001, Standard on Clean Agent Fire Extinguishing Systems
39. HIOSH Standards – Title 12, Subtitle 8, Hawaii Occupational Safety and Health Standards

23.2 COMPLIANCE

The prime responsibility for implementation of the F/LS criteria lies with the organizations responsible for the design and construction of the System. The SSORC shall develop and implement a review process to verify conformance with the criteria. The City and its contractors (including consultants) shall be responsible for establishing and maintaining a document control system to ensure submittal to SSORC of all relevant designs, specifications, and procedures for the entire Project. The SSORC shall be advised when any deviation from F/LS criteria occurs in any design, specifications, procedure, or aspect of construction.

23.3 REVISIONS

Revisions to the F/LS criteria shall be made following review and recommendations of the SSORC via the established document control procedure. The City and responsible organizations shall present to the SSORC suggested revisions to the F/LS criteria if changes in the Project result in changing the conditions, assumptions or data upon which the original F/LS criteria were based.

23.4 STATION FACILITIES

23.4.1 General

The primary purpose of a station is its use by transit patrons who normally stay in a station structure for a period of time no longer than necessary to wait for and enter a departing transit vehicle, or to exit the station after arriving on an incoming transit vehicle. In its entirety, it essentially functions as a means of accessing and egressing transit vehicles. A station is also for the use of employees whose work assignments require their presence in the station structures.

23.4.1.1 Application

A. The criteria are applicable to at-grade and elevated transit stations.

B. The criteria shall also be applicable to appurtenant facilities, including train control and communication room, electrical room, battery room, security room, mechanical room, elevator equipment room, station manager's booth, custodial room, trash room, and public/staff restroom.

23.4.1.2 Occupancy

A. The station public occupancy shall consist of all areas in which patrons may be allowed to enter, and shall include the full length of platforms, concourses, corridors, stairways, ramps, and passageways required for emergency egress.

B. The station ancillary occupancy shall consist of all spaces other than station public occupancies.

23.4.1.3 Codes and Standards

The design of stations and their appurtenances shall conform to NFPA 130, Chapter 5, and where applicable, the IBC, as administered by the City, except as specifically set forth in this section. For purposes of interpreting and applying the local code, transit stations shall be classified as assembly occupancies.

23.4.2 Types of Construction

A. Unless otherwise specified in this section, structures or portions of structures classified as stations of the fixed guideway transit system shall be not less than Type I or Type II construction or combinations of approved Type I and Type II non-combustible construction, as defined in NFPA 220 and NFPA 130, Subsection 5.2.1.

B. The station manager's booth shall be constructed of noncombustible materials conforming to the requirements of Paragraph 23.2.2.A.

C. Elevator shafts shall be of non-combustible construction.

23.2.2.1 Compartmentation and Fire Separation

Unless otherwise specified in this section, fire resistance ratings of separations between occupancies in all stations shall be established in accordance with IBC, Table 508.3.3.

A. The following areas/occupancies shall have a two-hour fire separation from all other occupancies:

1. Electrical control rooms, auxiliary electrical rooms and associated battery rooms (the two rooms to be considered as one), and elevator equipment room
2. Train control rooms and associated battery rooms (the two rooms to be considered as one)
3. Mechanical/fan rooms
4. Trash rooms
5. Bottom of an escalator truss

B. All public areas shall have a fire separation of at least two hours from non-public areas.

C. Exception: Restrooms do not require two-hour separation.

D. All station public areas shall have a fire separation of at least three hours from all non-transit occupancies.

E. The fire resistance rating of exterior walls shall be in accordance with NFPA 130. However, exterior walls of ancillary rooms shall not be less than the minimum fire resistance rating in this section.

F. The fire separation for stations may be modified based on an engineering analysis of potential fire exposure hazards, as approved by the City.

23.4.2.2 Doors and Openings

A. All openings (e.g., private entrances) from station public areas to all nontransit occupancies shall be protected by fire-protective assemblies complying with the requirements of NFPA 130. The fire-protective assemblies shall be of appropriate rating for the location in which they are installed.

B. The fire doors shall conform to the fire-protection rating of NFPA 130.

C. Door openings in two-hour-rated walls shall be fitted with 1.5-hour rated doors with appropriate hardware.

D. Where a fire door is required to be open, one of the following shall apply:

1. The door shall be of the automatic closing type

2. The door shall be activated by listed smoke detectors

3. Where a separate smoke barrier is provided, the operation shall be permitted to be by fusible links

E. Fire door assemblies shall be installed in accordance with NFPA 80.

F. Glazing in fire door assemblies shall comply with NFPA 80.

G. Window walls or other glazed separation shall be permitted between the Project's public areas and non-project occupancies provided the required fire resistance rating is maintained. Glazing in fire window assemblies shall be fire-protection rated in accordance with NFPA 130.

H. The out-of-doors shall be considered an "occupancy" only if it includes a public way such as a street or sidewalk within 15 feet of the station structure.

I. The maximum area of unprotected or protected openings in an exterior wall shall be in accordance with NFPA 130.

23.4.2.3 Elevators and Escalators

A. Elevators shall be designed to accommodate the loading and transport of an ambulance gurney or stretcher in its horizontal position.

B. Elevators shall comply with the requirements of 49 CFR Part 37, Appendix A, Section 4.10 and Paragraph 10.3.1 (17) and ASME A17.1.

C. Noncombustible hydraulic fluid shall be used in elevators.

D. Escalators shall comply with the requirements of NFPA 130, Subsection 5.5.2.

23.4.2.4 Interior Finishes

A. Interior finishes of all surfaces exposed to the interior of the building, including fixed or movable walls and partitions, columns, and ceilings, enclosed exit access routes and exits, ancillary areas, and the platforms and concourses in transit stations, shall be in accordance with NFPA 130, Section 5.10.

B. Interior floor finish materials in stations shall be noncombustible or shall exhibit a critical radiant flux not less than 0.8 W/cm^2 when tested in accordance with ASTM E 648.

23.4.3 Ventilation

Ventilation systems in ancillary areas shall be in accordance with Chapter 19, Facilities Mechanical, and as described below:

A. Ancillary area ventilation systems shall be arranged so that air is not exhausted into station public occupancy areas. Controls for shutdown of ancillary area ventilation systems shall be provided at the OCC and/or at local controls. Installation of such systems shall be in accordance with NFPA 90A.

B. Storage battery or similar ancillary rooms in which hydrogen gas or other hazardous gases may be released shall require mechanical ventilation and shall be ventilated in accordance with NFPA 91, and NFPA 130, Subsection 7.3.6.

C. Operation of the mechanical ventilation system shall be independent of room temperature.

D. Exhaust ducts from battery rooms shall not connect with duct systems used for other purposes.

E. Ventilation shall be provided for battery rooms and cabinets in accordance with Chapter 19, Facilities Mechanical. The battery exhaust ventilation system, where provided, shall meet one of the following requirements:

1. The ventilation system shall be designed to limit the maximum concentration of hydrogen to 1.0 percent of the total volume of the room during the worst-case event of simultaneous "boost" charging of all the batteries, in accordance with nationally recognized standards.

2. Continuous ventilation shall be provided at a rate of not less than 1 $ft^3/min/ft^2$ (5.1 $L/sec/m^2$) of floor area of the room or cabinet.

23.4.4 Electrical Requirements

Electrical equipment and wiring materials and installations within stations, other than for traction power, shall be in accordance with Chapter 20, Facilities Electrical, and shall satisfy the wiring requirements of NFPA 70 and NFPA 130, Section 5.4.

A. For all stations, an acceptable back-up power supply shall be provided for critical F/LS systems that will include, but not be limited to, the following:

1. Fire detection, alarm and suppression systems

2. Emergency telephone

3. Emergency lighting to include top and bottom of escalator landings

4. Indicator for elevators and escalators

5. Variable-message sign system to include any automated emergency messages

6. Closed Circuit Television

7. Public address system

B. Conductors for emergency lighting and communications shall be protected from physical damage by transit vehicles or other normal transit system operations, as well as from fires in the transit system in accordance with NFPA 130, Subsection 5.4.8.

C. Traction Power and Electrical Wiring and Cable – Comply with the applicable requirements identified herein.

23.4.5 Means of Egress

The transit station shall comply with the applicable provisions of NFPA 130, except as modified herein. Means of egress shall be in compliance with the following:

A. Passenger Station Exiting Requirements: Exiting for transit stations shall be in compliance with NFPA 130, Section 5.5. The objective shall be to provide sufficient exiting to clear a station in a required time period. The exiting calculations shall take into consideration trainloads, peak operating periods, surge factors, and entraining loads as defined in NFPA 130. A minimum surge factor of 1.5 shall be applied as a distribution curve correction to account for the peak within the peak-hour ridership.

B. Station Ancillary Occupancy Areas: Means of egress shall be arranged in accordance with NFPA 130.

C. Areas of Refuge: Areas of refuge are not required at emergency exit stairways serving open stations. Concourse shall be considered an area of refuge in stations with concourse.

23.4.5.1 Emergency Lighting and Exit Signs

Emergency lighting and exit signs shall be in accordance with Chapter 20, Facilities Electrical, and as described below:

A. Station structures shall be provided with a system of emergency lighting complying with the requirements of NFPA 130, Section 5.6.

B. Exits shall be marked with readily visible signs complying with the requirements of NFPA 101. Where emergency lighting is required, exit signs shall be illuminated by the emergency lighting source.

C. Exit lights, essential signs, and emergency lights shall be included in the emergency lighting system and shall be powered by a standby power supply or a supply independent of the traction power system. Emergency fixtures, exit lights, and signs shall be separately wired from emergency distribution panels.

D. Emergency lighting for stairs, ramps, and escalators shall be designed to emphasize illumination on the top and bottom steps and landings. All newel- and comb-lighting on escalator steps shall be on emergency power circuits. A minimum of one foot-candle of emergency lighting shall be provided throughout the entire run of each stair, ramp, and escalator.

E. Emergency exit facilities shall be suitably identified as exits and maintained to allow for their intended use.

23.4.6 Fire Protection

23.4.6.1 Protective Signaling Systems

The protective signaling system is addressed in Chapter 21, Fire and Intrusion Alarm Systems.

23.4.6.2 Standpipe System

A. Each elevated station and station locations with limited access shall be provided with a Class I manual-wet standpipe system, in accordance with NFPA 14.

B. Standpipe and hose systems shall be tested and maintained in accordance with NFPA 25.

23.4.6.3 Fire Extinguishers

A. Portable fire extinguishers shall be provided as required by the City according to hazard type and space utilization.

B. In electrical rooms, 10-B: C carbon dioxide extinguishers shall be provided.

C. At other locations, 4-A: 40-B: C extinguishers shall be provided.

D. Fire extinguishers are not required in open stations. (Exception: Ancillary rooms associated with an open station shall be equipped with an approved fire extinguisher.)

23.4.6.4 Fire Department Access to Stations.

A. Access to station entrances and emergency egress locations shall be from public streets, or an access road with a minimum paved width of 20 feet. An unobstructed vertical clearance of not less than 13 feet 6 inches shall be provided in accordance with UFC, Section 902.

B. An access road to a station shall be continuous from a public street to a public street, or a turnaround approved by the City shall be provided.

C. A fire department access road shall extend to within 100 feet of the fire department connection. FDC and hydrant spacing and locations shall be as approved by the City.

D. Any passenger station with locked ancillary spaces shall have a key lock box system as approved by the City. Keys required to access any part of the station shall be provided.

23.4.7 Trash Containers

Trash containers shall be manufactured of non-combustible materials.

23.4.8 Bicycle Racks

Bicycle racks shall be manufactured of non-combustible materials.

23.4.9 Seating Furniture

Seating furniture in stations shall be non-combustible or shall have limited rates of heat release when tested in accordance with ASTM E 1537, as defined in NFPA 130, Section 5.9.

23.4.10 Combustible Furnishings and Contents

Where combustible furnishings or contents not specifically addressed in this standard are installed in a station, a fire hazard analysis shall be conducted to determine that the level of occupant fire safety is not adversely affected by the furnishings and contents.

23.5 GUIDEWAY FACILITIES

23.5.1 General

The guideway shall be considered at-grade where track is placed on-grade without a supporting structure or roof; the guideway shall be considered elevated where the track is placed on an elevated structure.

23.5.2 Elevated and Surface Structures

A. Construction: all elevated structures necessary for guideway support and all structure and enclosures on or under guideways shall be of not less than Type I or Type II (000) or combinations of Type I or Type II-approved non-combustible construction, as defined in NFPA 220 and NFPA 130 Section 6.3.1.3. Structures under the guideway shall have non-combustible roof coverings.

   Construction materials of any at-grade or unroofed structure other than elevated structures shall be not less than Type II (000) approved noncombustible material, as defined in NFPA 220, and as determined by an engineering analysis of potential fire exposure hazards to the structure.

B. If other facilities such as train signaling equipment, communications equipment, or battery power supplies are incorporated into a traction power substation, occupancy separations shall be provided in accordance with IBC, Table 508.3.3. If such facilities are provided with separate structures, the structures shall comply with Paragraph 23.3.2.A.

23.5.3 Guideway Traction Power and Facility Wiring

Traction power elements associated with the guideway may include contact rail, contact rail supports, contact rail coverboard, wayside potheads, cable between pothead and contact rail, and special warning and identification devices. All wiring materials and installations other than those for traction power shall conform to the requirements of NFPA 70.

23.5.3.1 Contact Rail Protection

Contact rail protection shall be provided in accordance with NFPA 130, Section 6.4.2, and as defined below:

A. Contact rail conductors that supply power to transit vehicles for propulsion and other loads shall be secured to suitable insulating supports, properly bonded at joints, and properly protected to prevent contact with personnel.

B. The design shall include measures to prevent inadvertent contact with live power rails where such power rails are adjacent to emergency or service walkways and where walkways cross over guideways.

C. Coverboards shall be capable of withstanding a vertical load of 1100 N (247) lb. when applied at any point with no visible permanent deflection.

D. The protective coverboard provided on contact rail sections shall be securely anchored. Coverboard materials shall be electrically insulating and shall have a flame-spread rating index of not more than 25 and a smoke-developed index not exceeding 450 when tested in accordance with NFPA 255 (ASTM E 84) and/or NFPA 130, Subparagraphs 6.4.2.5.2 and 6.4.2.5.3.

E. The coverboard shall be permanently and conspicuously marked to provide basic location identification by section of guideway and electrification feeder zone. Markings should be at the ends of station platforms, at each end of each contact rail gap, and at intervals along the coverboard, not to exceed 500 feet.

23.5.3.2 Contact Rail Appurtenances

Cables connecting the contact rail, pot heads, and energized hardware shall be covered with insulating material and installed so as not to present a tripping or electrical hazard to personnel on the guideway. Insulating material for cables connecting power to the contact rail shall meet the requirements of IEEE Standard 383, Subsection 2.5.

23.5.3.3 Contact Rail Location

The contact rail shall be located opposite the station platform and the emergency walkway, except at special trackwork areas. Contact rail guards or appropriate coverboard protection shall be provided to prevent inadvertent contact with the contact rail where walkways are at track level and near the contact rail.

23.5.3.4 Traction Power Substation

A. TPSS shall use dry-type transformers.

B. All TPSS enclosures shall be of Type II – B non-combustible construction and have a Group F-1 occupancy classification in accordance with IBC requirements.

C. Fire protection

D. Heat and smoke detectors shall be installed at traction power substations in accordance with Chapter 21, Fire and Intrusion Alarm Systems.

E. Blue light station (BLS) shall be provided at TPSS in accordance with NFPA 130, Subsection 6.2.7 and Subsection 23.6.5.

23.5.3.5 Signage

Warning signs shall be posted on entrances to the guideway (e.g., station platforms), on fences or barriers adjacent to the guideway, and at other locations where unauthorized persons may attempt to enter the guideway. The warning sign shall clearly state the hazard (e.g., DANGER HIGH VOLTAGE — 750 VOLTS) with letter sizes and colors in conformance with NFPA 70 and Hawaii Occupational Safety and Health Division (HIOSH) standards.

23.5.4 Surface and Elevated Emergency Access

Emergency access shall be in accordance with NFPA 130, Subsection 6.2.3, and as defined below:

23.5.4.1 Surface

A. If security fences are used along the guideway, access gates shall be provided in security fences, as deemed necessary by the City.

B. Access gates shall be a minimum of 44 inches wide and shall be of the hinged or sliding type.

C. Information that clearly identifies the access route and location of each gate shall be provided on the gates or adjacent thereto.

D. Within the at-grade right-of-way, the maintenance vehicle access areas shall be suitable for use by emergency vehicles to conform with UFC fire department access requirements.

23.5.4.2 Elevated

A. Access to the guideway by emergency response personnel shall be through passenger stations or directly from crossing or parallel public streets by mobile ladder equipment. Where conditions such as landscaping, structures, or contiguous private property ownership hinder emergency response personnel, special provisions may be necessary.

B. If no adjacent or crossing roadways exist, access roads shall be provided at maximum intervals of 762 meters (2,500 feet).

23.5.5 Egress for Passengers

A. The system shall incorporate a walk surface or other approved means for passengers to evacuate a train at any point along the guideway so that they can proceed to the nearest station or other point of safety.

B. System egress points shall be illuminated in accordance with NFPA 130, Section 6.2.5. Guideway lighting may be by ambient sources (e.g., street lights, signs). In areas where ambient lighting does not provide adequate illumination, supplemental lighting may be required.

C. The illumination levels of elevated guideway walkways and walking surfaces shall not be less than 2.7 lx (0.25 foot-candles) at the walking surface.

D. Where the guideway track bed serves as the emergency egress pathway, it shall be nominally level and free of obstructions.

E. Walking surfaces shall have a uniform, slip-resistant design. Open grating surfaces shall not be permitted.

F. Raised walkways, ramps, and stairs shall be provided with a handrail that shall not obstruct egress from the train.

G. Crosswalks shall be provided at track level to ensure walkway continuity. Guards and handrails are not required on crosswalks.

H. Crosswalks shall have uniform walking surface at the top of the rail.

I. Walkway continuity shall be maintained at special track sections (e.g., crossovers, pocket tracks). Crosswalks at rail elevation, at least 30 inches wide, shall be provided along the full width of trackways at each end of special trackwork sections. Walkway routing shall avoid areas of switch points, switch machines, and/or frogs. Where the crosswalk is to extend to the side of the trackway with contact rail, the contact rail shall be discontinued not less than 5 feet from each side of the crosswalk.

J. A transition in the walkway shall be provided at the abutment of at-grade to aerial.

K. The means of egress within the guideway and accessible to persons getting off disabled trains shall be provided with an unobstructed clear width along the walking surface in accordance with NFPA 130, Paragraph 6.2.1.11.

L. Walkways designated for evacuation of passengers shall be constructed of non-combustible materials. Walkways shall have a reasonably regular surface and shall not have a slope exceeding one foot vertical to six feet horizontal. A single walkway may serve more than one track.

M. Raised walkways, ramps, and stairs shall be provided with a handrail that shall not obstruct egress from the train.

N. Passengers shall enter the guideways only in the event that it becomes necessary to evacuate a train.

O. Evacuation shall take place only under the guidance and control of authorized, trained system employees or other authorized personnel as warranted during an emergency.

P. Points of exit from elevated guideways shall be marked with internally or externally illuminated directional signs.

Q. Directional signs shall be readily visible by passengers for emergency evacuation.

R. Emergency exit facilities shall be identified and maintained to allow for their intended use.

23.5.6 Fire Protection of Wayside Train Control Rooms

Wayside train control rooms shall be protected by a clean agent fire extinguishing system.

23.6 PASSENGER VEHICLE

23.6.1 General

Transit vehicles shall, at a minimum, be designed and constructed to conform to the requirements of NFPA 130, Chapter 8, and Chapter 12, Passenger Vehicles, and as set forth in this section.

23.6.2 Equipment Arrangement

A. The vehicle equipment shall be arranged in accordance with NFPA 130, Section 8.3 and as defined herein.

B. Vehicle design shall arrange equipment external to the passenger compartment, whenever practical, to isolate potential ignition sources from combustible material and to control fire and smoke propagation.

C. Battery cases shall be spaced well away from compressed air sources and combustible materials at vehicle trucks and away from under-vehicle sources of high temperatures, such as resistor banks and compressors.

D. Toxicity: those materials and products generally recognized to have high toxic products of combustion shall not be used.

23.6.3 Fire Resistance

A. Structural fire resistivity shall comply with NFPA 130, Section 8.5, and the requirements defined herein.

B. All floor, wall, and roof openings and penetrations shall be adequately sealed/protected to maintain the fire and smoke integrity of the structure, in addition to mechanical considerations (e.g., waterproofing).

C. Vehicle end caps and floor shall be designed to preclude propagation of an under-floor fire to a vehicle's interior.

23.6.4 Flammability and Smoke Emission

The test procedures and minimum performance for materials and assemblies shall be as detailed in NFPA 130, Section 8.4.

23.6.5 Electrical Fire Safety

A. General Construction: all motors, motor control, current collectors, and auxiliaries shall be of a type and construction suitable for use on fixed guideway transit vehicles.

B. Clearance and Creepage: electrical circuits and associated cabling shall be designed with clearance and creepage distance between voltage potentials and car body ground in accordance with the requirements of NFPA 130, Subsection 8.6.2.

C. Propulsion Motors: propulsion motors shall meet the requirements of NFPA 130, Subsection 8.6.3.

D. Motor Control: motor control shall meet the requirements of NFPA 130, Subsection 8.6.4.

E. Propulsion and Braking System Resistors: propulsion and braking system resistors shall meet the requirements of NFPA 130, Subsection 8.6.5.

F. Current Collectors

1. The minimum size of current collector leads shall be determined by adding the maximum auxiliary loads to the propulsion motor loads.

2. The equivalent regenerative load shall be included in the propulsion system equipped with regenerative capability.

3. All current-carrying components shall be sized for continuous operation in the event power collection to the vehicle is restricted to a single collector.

G. Wiring: all wires and cables shall be listed as being resistant to the spread of fire and shall have reduced smoke emissions. Electrical insulation, cable and wire sizes, and wiring methods shall meet the requirements of NFPA 130, Subsection 8.6.7.

H. Overload Protection: a main, automatic circuit line breaker or line switch and overload relay for the protection of the power circuits shall be provided in accordance with NFPA 130, Paragraph 8.6.8.1. Main fuse protection shall be in accordance with NFPA 130, Paragraph 8.6.8.2. Auxiliary circuits used for purposes other than propelling the vehicle shall be connected to the main cable at a point between the current collector and the protective device for the traction motors and shall meet the requirements of NFPA 130, Paragraph 8.6.8.3.

I. Battery Installation: the design of battery installation and circuitry shall be in accordance with NFPA 130, Subsection 8.6.9.

23.6.6 Emergency Egress

Emergency egress facilities shall be provided in accordance with NFPA 130, Section 8.8 and as defined below.

23.6.6.1 Emergency Exits

A. Each vehicle shall have all doors equipped so that, in case of emergency, they can be easily opened by a passenger using readily apparent or disclosed means.

B. A means shall be provided to allow passengers to evacuate the vehicle safely to a walk surface or other suitable area under the supervision of authorized employees in an emergency.

23.6.6.2 Operation of Means of Emergency Egress

Means of emergency egress using doors shall be capable of being operated manually, without special tools, from the interior and exterior of the vehicle.

23.6.6.3 Marking and Instructions for Operation of Means of Emergency Egress

The interior and exterior marking and instructions for operation of means of emergency egress shall be in accordance with NFPA 130, Subsection 8.8.5.

23.6.7 Emergency Lighting and Power Supply

A. Emergency lighting facilities shall be provided such that the level of illumination of the means of egress conforms to the level of illumination required in Chapter 12, Passenger Vehicles.

B. The emergency lighting system power shall be automatically obtained from the storage batteries.

C. The emergency lighting system storage batteries shall have a capacity sufficient to maintain the minimum lighting illumination level specified in Paragraph 23.4.7.A for a period of time to permit evacuation but in no case less than one hour.

23.6.8 Heating and Ventilation Systems

A. Control of Ventilation Equipment − vehicles shall have a provision to deactivate all ventilation systems manually or automatically.

B. Heater Protection

   1. Heater-forced air distribution ducts and plenums shall incorporate overtemperature sensors, fusible links, airflow devices, or other means to detect overtemperature or lack of airflow.

   2. All heater elements shall incorporate protective devices for the following failures:

      a. Ventilation air flow, if appropriate

      b. Failure of temperature controls or occurrence of overtemperature conditions, as appropriate

      c. Short circuits and overloads in supply wiring

23.6.9 Portable Fire Extinguishers and Smoke Detectors

A. Each vehicle shall be provided with at least two UL-approved portable fire extinguishers of the 10-pound class, rated at 4-A: 30-BC. The extinguishers shall be located for use by patrons or the train attendant, as necessary.

B. Portable fire extinguishers shall be inspected and maintained in accordance with NFPA 10.

C. Smoke detectors shall be installed in each vehicle in proper relation to supply and return air ducts of the HVAC system. Activation of a smoke detector shall be alarmed at OCC.

23.6.10 Communications

A. Each vehicle shall be equipped with public address and variable-message sign systems by which OCC can make announcements to the passengers. Audibility level shall be a minimum of 10 decibels over any background noise. The design shall be in accordance with Chapter 15, Communications and Control.

B. Devices by which passengers may alert and communicate with OCC in emergencies shall be provided in each car. The design shall be in accordance with Chapter 12, Passenger Vehicles, and Chapter 15, Communications and Control.

C. Unauthorized opening of vehicle doors shall be automatically communicated to OCC.

D. Power for Communication Systems – the above communication systems shall be powered by the onboard emergency power supply.

23.7 MAINTENANCE AND STORAGE FACILITY

23.7.1 General

This section defines the F/LS requirements for design of the Maintenance and Storage Facility (MSF).

A. The MSF occupants shall be employees or contractors whose work assignment requires their presence in those facilities, as well as authorized visitors.

B. Applicable IBC, UFC, and HIOSH requirements shall be incorporated into the design of the MSF.

C. For the purpose of interpretation, the MSF occupancies shall be classified in accordance with IBC, Chapter 3 and as defined herein. The occupancies shall be separated and protected accordingly.

1. Repair Shops: Group F-1
2. Vehicle maintenance: Group F-1
3. Operations Control Center: Group B
4. Yard Control Tower: Group B
5. Train Control House: Group F-1
6. Train Wash Facility: Group B
7. TPSS: Group F-1
8. Car Body Shop: Group F-1
9. Parts Storage: Group S-2
10. Administrative Offices: Group B

11. Flammable Storage: Group S-1

12. Maintenance-of-Way (MOW) Facility.

    a. MOW Shops: Group F-1

    b. Vehicle/Equipment Storage: Group S-2

    c. MOW Office Areas: Group B

    d. Crew Rooms: Group B

D. Where the MSF buildings or portion thereof contain two or more occupancies or uses, the building or portion thereof shall comply with the applicable provision of IBC, Subsection 302.1 and Section 508.

E. Spaces that are incidental to main occupancies shall be separated or protected, or both, in accordance with IBC, Subsection 508.2 and Table 508.2, or the building shall be classified as a mixed occupancy and shall comply with IBC, Subsection 508.3.

23.7.2 Yard Facilities

23.7.2.1 Fire Protection Water Supply and Distribution

An adequate, reliable water supply shall be available for fire protection, including a sufficient number of properly located hydrants, approved by the City and in accordance with NFPA 24 and local fire ordinances.

A. Site fire flows (water supplies) and hydrants shall conform to applicable City codes.

B. Standpipe and automatic sprinkler water supplies shall meet the requirements of NFPA 13, NFPA 14, and local codes.

23.7.2.2 Emergency Access/Egress

A. Emergency access approved by the City shall be provided to system structures, guideway facilities, yards, and outside storage areas in accordance with appropriate local ordinances.

B. Access to any structure shall be from public streets or fire apparatus access roads.

C. Access to the inside perimeter of the transit vehicle yard and maintenance facility area shall be by MSF circulation roads. Such access roads shall provide two separate but interconnected means of ingress and egress.

D. Access roads shall be provided in accordance with UFC and as approved by the City. Pavement design of access roads shall provide for an all-weather hard surface roadway.

E. Access road shall have a vertical clearance as required by the City. Dead-end fire apparatus access roads shall be provided with approved provisions for the turning around of fire apparatus.

F. Yard tracks shall allow a minimum clearance of 4 feet between the sides of adjacent transit vehicles. Prime consideration shall be given to providing a clear exit path to evacuate personnel in an emergency.

23.7.2.3 Fire Extinguisher

Portable fire extinguishers of adequate size and rating shall be provided, suitably housed, and spaced throughout the MSF's open areas in accordance with NFPA 10 and as required by the City.

23.7.2.4 Blue Light Stations and Communications

A. Blue Light Stations (BLS) as described herein shall be provided as follows:

1. At MSF TPSS
2. At both ends of storage track arrays
3. At emergency accesses to the yard. A BLS is not required at an emergency entrance if it is within 300 feet of a BLS in the yard and that BLS is within line of sight from the emergency access and not obscured by normally parked transit vehicles.

B. Communications: provisions shall be made within the property to summon the local fire department in accordance with provisions contained in NFPA 72, Chapter 9 Public Fire Alarm Reporting Systems.

23.7.3 Structures

23.7.3.1 Structural Facilities

A. Structures shall be of non-combustible construction in accordance with IBC.

B. Fire separations shall be provided and maintained to separate occupancies as required by IBC.

C. Emergency exiting for maintenance facilities shall be as required by IBC.

D. Emergency Lighting: emergency lighting shall be provided for all exits within the maintenance facilities, in accordance with IBC.

23.7.3.2 Drainage Systems

A. Where there is a potential for fire and/or explosion, drainage systems shall use non-combustible piping. Where piping is not enclosed, as direct a routing as possible to a safe outside location shall be provided.

B. Oil separators and grease and sand traps shall be installed on all floor drainage systems that service maintenance and transit vehicle storage areas to provide for the extraction of oil, grease, sand, and other substances that are harmful or hazardous to the structure or public drainage systems. Separators and grease traps shall be of approved design and of sufficient capacity to meet the level of waste discharged from the areas. The separator storage capacity shall be of sufficient size to retain all sludge between cleanings.

C. Periodic maintenance checks and flushing shall be conducted on all drains, oil separators, and grease traps to ensure they are clear of obstructions and perform their designed function. Any flammable liquids and greases shall be sent to an approved disposal facility.

23.7.3.3 Floors

The surface of the grade floor of storage or maintenance areas shall be of non-combustible slip-resistant material.

23.7.3.4 Roofs

Roof coverings shall comply with IBC, Table 1505.1 based on the type of construction of the building. The listed roof assemblies and roof coverings shall be tested in accordance with IBC, Subsection 1505.1.

23.7.3.5 Electrical Requirements

A. The installation of electric wiring for structure light and power and the installation of all electrical devices not supplying traction power shall be in accordance with Chapter 20, Facilities Electrical, as well as applicable local codes.

B. Traction power equipment shall meet the following requirements:

1. Power Rail Conductors: contact rails supplying power to transit vehicles for propulsion and other loads shall be secured to suitable insulating supports, properly bonded at joints, and properly guarded to prevent contact with personnel.

2. Emergency Power Shutoff: all traction power circuits shall have emergency power shutoff devices or means in accessible locations.

23.7.3.6 Maintenance Pit Areas

A. Where flammable/combustible liquids and/or hazardous materials are used in pit areas and associated below-floor level areas, such areas shall be designed to meet local code provisions.

B. Walls, floors, and piers shall be constructed of masonry or concrete.

C. Pits shall have at least 2 exits. Steps shall be non-combustible and constructed with no free space underneath.

D. Pits and sub-floor work areas shall be kept clean. Smoking shall be prohibited in pits and sub-floor maintenance areas.

23.7.3.7 Overhead Cranes

Overhead cranes installed in the maintenance area shall adhere to the standard for cranes and hoists as required by NFPA 70, Article 610.

23.7.3.8 Ventilation

A. Under-floor ventilation: in all pit areas where undercar maintenance can generate fumes of a combustible nature, a positive mechanical exhaust ventilation system shall be provided that is capable of 10 air changes per hour or 1 cfm/ft^2 of pit floor area, whichever is greater, during normal operation and shall be designed to discharge to the outside atmosphere.

B. Above-floor ventilation: when a mechanical ventilation system is employed in shop maintenance areas, the ventilation system shall be designed and installed in accordance with NFPA 90A. When blower and exhaust systems are installed for vapor removal, the systems shall be designed and installed in accordance with NFPA 91.

C. Battery area ventilation: areas where batteries are charged shall be well-ventilated to the outside to ensure that the maximum hydrogen-air mixture that may be generated during charging is held below the lower explosive limits. In addition, where mechanical ventilation systems are required, they shall be installed in accordance with NFPA 91. The battery exhaust ventilation system shall be provided with electrical power and airflow interlocks that will prevent operation of the battery charger if the ventilation fan motor is not energized or the air velocity in the exhaust duct is less than the designed velocity. The entire electrical system shall be in accordance with NFPA 70.

D. Large building open areas require a means for smoke and heat venting.

E. Smoke and heat vents and draft curtains, where required, shall be in conformance with IBC, Section 910.

23.7.4 Fire Protection Systems

23.7.4.1 Automatic Suppression Systems

A. An approved automatic sprinkler system shall be installed in all areas of enclosed structures used for storage and maintenance of transit vehicles.

B. The sprinkler system shall be of a closed-head type for ordinary hazard classification installed in accordance with NFPA 13 and IBC, Section 903.

C. Electronic maintenance areas shall have an automatic sprinkler system or other City-approved fire extinguishing system in accordance with NFPA and local codes.

D. Sprinkler systems for storage areas where racks, shelves, or other storage devices are used shall comply with NFPA 13 and local codes, as appropriate.

23.7.4.2 Protective Signaling Systems

Automatic fire detection and alarm systems, where required, shall be installed conforming to NFPA 72 and Chapter 21, Fire and Intrusion Alarm Systems.

23.7.4.3 Standpipe Systems

A. Where standpipes and connections are required by the City, the standpipe system shall comply with the requirements of NFPA 14 and IBC, Chapter 9.

B. The spacing of standpipes in large open areas of the MSF requires special design consideration to obtain hose stream access around, under, and within vehicles.

23.7.4.4 Portable Fire Extinguishers

A. Portable fire extinguishers shall be installed throughout all MSF buildings in accordance with NFPA 10, local codes, and as defined below.

B. Number and capacity: the number and capacity of fire extinguishers shall be as required by the City.

C. Offices and storerooms: offices and storerooms other than those containing flammable liquids and greases shall be provided with listed Class A extinguishers.

D. Hazardous areas: areas in which flammable or combustible liquids, greases, or chemicals are used or stored shall be provided with listed extinguishers for Class A, B, and C fires.

E. Additional locations: in proximity to cranes or monorails used for hoisting or transporting heavy rail equipment, fire extinguishers suitable for Class B and C fires shall be located as defined by the City.

23.7.5 Operations and Maintenance

23.7.5.1 Vehicle Placement

Inside the MSF building, transit vehicles shall be placed and tracks shall be arranged to allow a minimum clearance of 3 feet 0 inches between the sides of adjacent transit vehicles and 2 feet 6 inches between the ends of two uncoupled cars. A clear exit path to evacuate personnel from the structure in an emergency shall be maintained in accordance with IBC.

23.7.5.2 Painting/Cleaning/Paint Removal

A. In selecting materials for cleaning and paint removal purposes, non-flammable materials shall be specified whenever possible. The use of flammable or combustible cleaning agents shall be in accordance with NFPA 30 and local codes.

B. Any locations in which painting or cleaning is to be done shall provide good general ventilation, ease of cleanup, and convenience.

C. The use of heat lamps to accelerate the drying of painted surfaces shall be prohibited unless used as part of an approved drying booth or enclosure in accordance with NFPA 33 and local codes.

D. For touch-up operations, any ignition sources within the areas being worked shall be eliminated; such areas shall be maintained hazard-free during the work period.

23.7.5.3 Storage of Painting/Cleaning Liquids

Storage of painting/cleaning liquids shall be in accordance with NFPA 30 and local codes.

23.7.5.4 Industrial Trucks

A. Industrial trucks shall mean fork trucks, tractors, platform lift trucks, and other specialized industrial trucks. The operation and use of industrial trucks shall be in accordance with NFPA 505 and ANSI/ITSDF B56.1.

B. The storage and handling of liquefied petroleum gas (LP-Gas) shall be in accordance with NFPA 58, NFPA 505, and local codes.

C. The storage and handling of liquid fuels, such as gasoline and diesel fuel, shall be in accordance with NFPA 30, NFPA 505, and local codes.

23.7.5.5 Other Requirements

Provision shall be made for the removal of all flammable or combustible liquids and greases to an approved disposal or storage area.

23.8 COMMUNICATIONS

23.8.1 General

A. Communications systems requirements are defined in Chapter 15, Communications and Control. To support F/LS criteria, the communications systems must operate in both normal and emergency modes. F/LS criteria place requirements upon the communications systems that are over and above those for normal operation. These additional requirements reflect the need to provide emergency voice communications capabilities and to provide data to operating and emergency response personnel during an emergency.

B. In general, system emergency voice communications shall be provided by the same subsystems as used for normal operation functions. Table 23-1 indicates the points between which emergency voice communications capability shall be provided. The additional requirements that must be met by these subsystems in order to fulfill F/LS functions are contained in the following paragraphs.

23.8.2 Operations Control Center Communications

A. To provide the fundamental emergency coordination for all rail transit trains and facilities in conformance with NFPA 72, the OCC shall be equipped to achieve the following:

1. Receive, log, and annunciate fire alarms, trouble alarms, and supervisory alarms

2. Receive, record, and log emergency telephone messages

3. Have portable, radio-based voice radio communications within moving trains

4. Have direct-line telephone communication with the City's emergency services dispatch facility

5. Have the capability to use the station's public address and variable-message sign systems to advise and direct patron response to emergencies

6. Have the capability to receive and respond to passenger train emergency speakerphone (T-TEL) calls placed from trains

7. Have the capability for emergency removal of traction power

Table 23-1 - DIRECT EMERGENCY VOICE COMMUNICATIONS MATRIX

	OCC	Patrons on Trains	Patrons in Stations	Emergency Response Organization	On-duty Transit Personnel	Patrons in Elevators
OCC		X	X	X	X	X
Patrons on Trains	X					
Patrons in Stations	X					
Emergency Response Organization	X		X		X	
On-duty Transit Personnel	X		X	X		
Patrons in Elevators	X					

23.6.2.1 Emergency Management Panel (EMP)

A. EMPs shall be provided for the purpose of consolidating all necessary on-site control and communication facilities necessary for effective response to emergencies. The EMPs shall be located next to the primary entrances, as described in Chapter 21, Fire and Intrusion Alarm Systems, as approved by the City.

B. EMPs shall have provisions for the following functions, as described in Chapter 15, Communications and Control, and Chapter 21, Fire and Intrusion Alarm Systems:

1. Telephone

2. Annunciation from the fire alarm control panel (FACP)

3. PA and VMS system access

4. Appropriate graphics

23.8.3 Emergency Functions Requiring Communication

A. Alarm and Notification

Alarm and notification communication facilities shall be provided to advise of an emergency condition for the following interface situations.

1. Communications between OCC and the following:

   a. Patrons on trains and in stations

   b. Transit personnel (operations/maintenance)

   c. Emergency response agencies (e.g., fire, police, medical)

   d. Two-way communications to elevator cars in accordance with ASME A17.1, Subsection 2.27.

2. Communications between station manager and the following:

   a. Patrons in stations

   b. OCC

   c. Other transit personnel (e.g., maintenance, operations)

   d. Transit system law enforcement

3. Fire detection alarm to OCC and EMP, as described in Chapter 21, Fire and Intrusion Alarm Systems.

B. Emergency power removal and train stopping requirements shall primarily be met through alarm or notification to OCC. Where potential hazards require immediate action, on-site traction power removal devices (ETS) shall be provided.

C. Tactical communication is required for each responding organization to provide operations control at the site of an emergency. The dispatching communications for public emergency organizations shall be their own equipment.

23.8.4 Telephones

A. The System shall have a telephone network in accordance with NFPA 130 and as described in Chapter 15, Communications and Control.

B. The emergency telephone (E-TEL) system shall be provided for the transit system in accordance with NFPA 130, as described in Chapter 15, Communications and Control, and as defined herein.

C. The E-TEL system shall enable a person on the operating line to communicate directly with OCC to report an emergency condition. The E-TEL may be used by the public, employees, and emergency personnel.

D. Operation of any E-TEL shall require pressing the push button on the E-TEL faceplate. This action shall cause an emergency indication to be displayed and an audible alarm to sound at an attended workstation at OCC. The indication shall identify the E-TEL geographic location.

E. E-TEL shall be provided at locations defined in Chapter 15, Communications and Control.

F. OCC shall have the capability to record telephone conversations on a master recording system as described in Chapter 15, Communications and Control. The recording system shall have instant replay capability for verification of emergency messages.

23.8.5 Blue Light Station (BLS)

A. Blue Light Stations shall be provided in accordance with NFPA 130, as described in Chapter 15, Communications and Control, at the following locations:

1. Ends of station platforms
2. Emergency access points, as required
3. Traction power substations
4. MSF
5. Other locations, as required

B. Activation of the ETS at any BLS shall trip the traction power feeder breakers for all tracks in the power zone covered by the BLS. The device shall provide local mechanical lockout capability, which shall preclude restoration of power until the mechanical lockout is reset. OCC shall have the ability to selectively restore power to any power zone in which the ETS has been activated.

C. An E-TEL shall provide communication to OCC. This phone is intended for fire or other emergency uses.

D. Integration of E-TEL and ETS operation shall be as provided in Chapter 15, Communications and Control.

E. Adjacent to each BLS, graphic information shall be provided that identifies the power zone affected and location of that station.

F. BLS shall be housed in an enclosed cabinet with an access door/panel that is alarmed as provided in Chapter 21, Fire and Intrusion Alarm Systems. Access door/panel shall be clearly marked with language warning of access to high voltage controls and of applicable City ordinance.

23.8.6 Public Address and Variable Message Sign Systems

A. Trains and stations shall have public address (PA) and variable-message sign (VMS) systems for communicating with passengers and employees in accordance with NFPA 130 and as described in Chapter 15, Communications and Control.

B. OCC shall have the capability of using the PA and VMS systems to make announcements throughout stations. The VMS system shall be designed to display messages in synchronization with audible messages via the PA system.

C. The capability of making announcements throughout a station on the PA and VMS systems shall be provided from the EMP.

D. OCC shall have the capability of making announcements throughout the trains on the vehicle PA and VMS systems. During interruptions of train service or delays for any reason associated with an emergency, fire, or smoke, the passengers and employees shall be kept informed by means of system-generated and real-time announcements.

E. At times of emergency, the PA and VMS systems shall be used effectively to communicate with passengers, employees, and emergency personnel.

F. Override access to the passenger stations or maintenance facility's PA and VMS systems shall be provided at EMPs associated with the specific facility.

23.8.7 Fire Alarm System

The fire alarm system, where required, shall be in accordance with Chapter 21, Fire and Intrusion Alarm Systems.

23.8.8 Portable Powered Speakers (Audiohailers)

During emergency operations, portable powered speakers shall be made available where other forms of communication are not available.

23.9 OPERATIONS CONTROL CENTER

23.9.1 General

A. This section defines the F/LS requirements for the design of the Operations Control Center (OCC).

B. The OCC shall be the central point for coordinating all train operations, station operations, and traction electrification, as well as for communicating directly with patrons in trains and at stations, and maintenance, supervisory, and emergency personnel (as required).

C. The OCC shall be a controlled space housing offices, equipment, and supporting facilities for use by those responsible for train control, communications, and fire and security management.

D. OCC shall be the portion of the facility used for data processing, status reporting, and transit system control, and excludes ancillary spaces and supporting facilities.

E. The OCC shall be arranged and equipped to function as the proprietary supervising station for the entire system, in accordance with NFPA 72. The area shall be used for the OCC and similar activities and shall not be jeopardized by adjoining or adjacent occupancies.

F. During normal operations, the OCC shall provide primary control of transit operations. During emergencies, emergency response personnel shall be responsible for control, supervision, and coordination of emergency activities. The OCC shall retain responsibility for operation of unaffected parts of the system and coordinate transit system response in the emergency area.

G. The OCC shall be equipped to provide the following functions:

1. Receive, log/printout, and annunciate fire, security, and supervisory alarms
2. Receive, record, and log E-TEL messages, including designation of the origin of the call
3. Communicate with on-duty transit personnel
4. Receive and respond to T-TEL calls placed from the trains
5. Use of the PA and VMS systems, as needed
6. Selectively remove and restore traction power
7. Have direct-line telephone communication with the dispatch facilities of appropriate fire and emergency response jurisdictions
8. Monitor seismic events

H. The OCC shall provide the City's emergency service providers with the capability of coordinating emergency operations from the OCC. This shall include access to the following:

1. PA and VMS system displays
2. Direct line to the City's emergency services dispatch center
3. E-TEL system
4. Fire detection, sprinkler valve, and water flow detector annunciator displays
5. Standby power status indicators
6. Monitoring of selected City emergency services radio channels

I. An alternate location shall be provided in the event the OCC is out of service for any reason and shall be equipped or have equipment readily available to function as required.

23.9.2 Construction and Location

A. The OCC shall not be located above, below or adjacent to areas or other structures where hazardous processes are located, unless approved protective features are provided.

B. The OCC shall be located in an area separated from other uncontrolled public access areas and any other occupancy by two-hour fire-resistant-rated construction, and as defined below:

1. Openings in the fire-resistant-rated construction shall be protected to limit the spread of fire and restrict the movement of smoke from one side of the fire-resistant-rated construction to the other. The fire resistance rating for doors in two-hour fire-resistant-rated construction shall be 1.5 hours.

2. The OCC data processing and control areas shall be separated from other occupancies in the OCC area by fire-resistant-rated construction. The fire resistance rating shall be commensurate with the exposure, but shall not be less than one hour.

3. The routing of all cabling to transit system operating areas and other services essential to the operation of the OCC shall be separated from other occupancies and buildings by minimum two-hour fire-rated separations.

4. Where any pass-throughs or windows are provided in any fire-rated wall of the OCC, each opening shall be equipped with an automatic fire-rated shutter or a fire-rated window of equal rating to the wall. The shutter shall be operated automatically by the presence of either smoke or heat on either side of the wall. Installation shall be in accordance with IBC, Chapter 7.

5. Air ducts shall be provided with automatic fire and smoke dampers where the ducts pass through fire-resistant-rated construction.

6. Egress routes serving the OCC and other occupancies shall be two-hour fire-rated enclosures, with self-closing and latching, 1.5-hour-rated doors. Access to the OCC building shall meet the requirements of IBC.

7. All other protection of vertical openings shall be in accordance with IBC.

8. A structural floor whereon OCC equipment is located, or that supports a raised floor installation, shall incorporate provisions for drainage from domestic water leakage, sprinkler operation, coolant leakage, and fire-fighting operations.

23.7.2.1 Materials

A. All structural assemblies and building appurtenances in OCC areas shall be of non-combustible materials.

B. Exposed cellular plastics shall not be used in OCC construction.

C. Only approved self-extinguishing-type trash receptacles shall be used in the OCC area.

23.9.2.2 Interior Finishes

A. Interior finishes consisting of all surfaces exposed to OCC areas of the building, including fixed or movable walls and partitions, columns, and ceilings, shall meet IBC, Chapter 8 requirements for Class A and B interior finishes.

B. Interior wall and ceiling finishes in the OCC area shall be Class A, in accordance with IBC, Section 803.

C. Interior finishes in all other areas shall be Class A or B, in accordance with IBC, Section 803.

D. Interior wall and ceiling finishes in fully sprinklered OCC areas shall be permitted to be Class B, in accordance with IBC, Section 803.

E. Interior floor finishes used in OCC areas shall be Class I, in accordance with IBC, Section 804.

F. Interior floor finishes in fully sprinklered OCC areas shall be permitted to be Class II, in accordance with IBC, Section 804.

23.9.2.3 Raised Floors

A. Structural supporting members for raised floors shall be of non-combustible material.

B. Decking for raised floors shall be one of the following:

1. Non-combustible.
2. Pressure-impregnated, fire-retardant-treated lumber having a flame-spread rating of 25 or less, in accordance with NFPA 255.
3. Wood or similar core material that is encased on the top and bottom with sheet, cast, or extruded metal, with all openings or cut edges covered with metal or plastic clips or grommets so that none of the core is exposed, and that has an assembly flame-spread rating of 25 or less, in accordance with NFPA 255.

C. Access sections or panels shall be provided in raised floors so that all space beneath is accessible. Tools needed to provide access to the underfloor space shall be located in the room, and their location shall be well-marked.

D. Electrical cable openings in floors shall be made smooth or shall be otherwise protected to preclude the possibility of damage to the cables and to minimize the entrance of debris or other combustibles.

23.9.3 Means of Egress and Emergency Access

A. The OCC shall comply with the minimum egress requirements of IBC, Chapter 10.

B. The OCC shall be located in a building that is adjacent to existing public streets and/or other access routes.

23.9.4 Building Services and Utilities

23.9.4.1 Fire Protection Water Supply

Fire protection water supply shall be as provided herein.

23.9.4.2 Heating, Ventilation, and Air Conditioning Systems (HVAC)

A. Any HVAC system that serves other occupancies shall also be permitted to serve the OCC area.

B. Battery storage or similar ancillary rooms, in which hydrogen gas or other hazardous gases may be released, shall be ventilated per UFC, Article 64.

23.9.4.3 Personnel Facilities

Personnel facilities shall be provided near the OCC so that on-duty operating personnel are continuously available.

23.9.5 Fire Protection

The OCC shall be protected by fire detection and suppression equipment such that there will be early detection and extinguishment of any fire in the OCC.

23.9.5.1 Fire Alarm System

A fire alarm system complying with the requirements of the UFC and NFPA 72 shall be provided for protection throughout the building housing the OCC, as specified in Chapter 21, Fire and Intrusion Alarm Systems.

23.9.5.2 Automatic Fire Detection

An automatic fire detection system, complying with the requirements of NFPA 72, shall be provided throughout the OCC building, as specified in Chapter 21, Fire and Intrusion Alarm Systems.

23.9.5.3 Fire Extinguisher

A. Listed portable fire extinguishers of the carbon dioxide type or a halogenated agent type or of the type and size approved by the City shall be installed throughout the OCC to protect electronic equipment. Extinguishers shall be maintained in accordance with NFPA 10.

B. Listed extinguishers with a minimum rating of 2-A shall be provided for use on fires in ordinary combustible materials, such as paper and plastics. Dry chemical extinguishers shall not be permitted.

C. A sign shall be located adjacent to each portable extinguisher and shall plainly indicate the type of fire for which it is intended.

23.9.5.4 Standpipe Systems

Standpipes shall be installed in the building housing the OCC. The standpipe system shall conform to the requirements of IBC, Section 905 and local codes.

23.9.5.5 Fire Extinguishing Systems

A. An automatic sprinkler system or other City-approved fire extinguishing system shall be provided throughout the OCC. The automatic sprinkler system shall be hydraulically calculated and designed in accordance with NFPA 13 and IBC, Chapter 9.

B. An automatic sprinkler system, pre-action automatic sprinkler system, carbon dioxide extinguishing system, inert agent fire extinguishing system, or other City- approved fire extinguishing system shall be provided to protect the area below the raised floor in the OCC.

C. A single-interlock pre-action automatic sprinkler system or other City-approved fire extinguishing system shall also be provided for other areas containing critical communications, telephone, and train control equipment and systems, such as tape storage rooms.

D. Sprinkler systems protecting information technology equipment areas shall be valved separately from other sprinkler systems.

E. Automatic sprinkler systems protecting OCC areas shall be maintained in accordance with NFPA 25.

23.9.6 Electrical Requirements

This section covers equipment, power-supply wiring, equipment interconnecting wiring, and grounding of OCC equipment and systems.

23.9.6.1 Electrical Service

A. All wiring shall conform to NFPA 70. Wiring in an air space below a raised floor or above a suspended ceiling, where such space is used to circulate OCC area environmental air shall conform to NPFA 70, Article 645.

B. Premise transformers installed in the OCC area shall be of the dry type or type filled with a non-combustible dielectric medium. Such transformers shall be installed in accordance with the requirements of NFPA 70.

C. Service entrance transformers shall not be permitted in the electronic information technology equipment area.

D. Protection against lightning surges shall be provided in accordance with the requirements of NFPA 70.

E. Junction boxes shall be completely enclosed, fastened, accessible, and grounded. No splices or connections shall be made in the underfloor area except within junction boxes or City-approved-type receptacles and connectors.

23.9.6.2 Lighting and Power

A. The OCC shall be provided with an automatic emergency lighting system, in accordance with NFPA 72 requirements for a Proprietary Supervising Station.

B. The emergency power source shall be independent of the primary lighting source, such that the loss of utility electrical power shall not impair any OCC functions. The on-site emergency power system shall be provided as described in Chapter 20, Facilities Electrical.

C. In the event of a loss of the primary lighting for the OCC, the emergency lighting system shall provide illumination for a period of not less than 26 hours to permit operators to continue operations, and shall be tested in accordance with the requirements of NFPA 72 for a Proprietary Supervising Station.

23.9.6.3 Supply Circuits and Interconnecting Cables

Supply circuits and interconnecting cables shall comply with the requirements of NFPA 75, Section 10.4.

23.9.6.4 Power Disconnecting Means

A means shall be provided to disconnect power to all electronic equipment in the OCC, in accordance with NFPA 75, Subsection 10.4.7.

23.9.6.5 Uninterruptible Power Supply (UPS)

Installation of UPS shall comply with the provisions of NFPA 70, Article 685, and NFPA 75, Subsection 10.4.8.

23.9.6.6 Grounding

All exposed non-current-carrying metal parts of an information technology system shall be grounded in accordance with NFPA 70, Article 250, or shall be double-insulated

23.10 PARKING STRUCTURE

23.10.1 General

A. The parking structure shall comply with applicable IBC requirements and as described in this section.

B. The parking structure shall be an “open parking garage” as defined in IBC, Subsection 406.3, and in Chapter 10, Architecture.

C. The parking structure shall be used exclusively for the parking of private motor vehicles, with no other uses in the structure other than those permitted exceptions in IBC, Subparagraph 406.3.5.1.

D. The open parking structure shall be classified as low-hazard storage, Group S-2 occupancy as defined in IBC, Subsection 311.3.

23.10.2 Construction

A. The open parking structure shall be of Type I, II, or IV construction as defined in IBC, Paragraph 406.3.3. The openings in the structure shall meet the requirements of IBC, Subparagraph 406.3.3.1.

B. The parking facility shall be constructed in accordance with IBC, Section 406.2.

C. The area and height of the structure shall comply with IBC, Table 406.3.5, with increases allowed by IBC, Subsection 406.3.6.

D. Floor surfaces shall be of concrete or similar non-combustible material and liquid-tight. Asphalt parking surfaces shall be permitted on grade.

E. Floors shall be graded and equipped with drains.

23.10.3 Fire Separation

A. The fire resistance rating of the parking structure's exterior walls and openings in exterior walls shall comply with IBC, Tables 601 and 602. The fire separation distance to an adjacent lot line and fire resistance rating of exterior walls shall be determined in accordance with IBC, Table 602 and Section 704.

B. A fire-resistance rating shall not be required for corridors in the open parking garage.

23.10.4 Means of Egress

A. The means of egress for the open parking structure shall meet the requirements of IBC, Subsection 406.3.8.

B. No fewer than two means of egress shall be provided from every floor or section of the parking structure.

C. In a ramp-type open parking structure with open vehicle ramps not subject to closure, the ramp shall be permitted to serve in lieu of the second means of egress from floors above the level of exit discharge, provided that the ramp discharges directly outside at the street level and is designed for pedestrian access.

D. A common path of egress travel shall be permitted for the first 75 feet from any point in the parking structure, as defined in IBC, Section 1014.3.

23.10.5 Travel Distance to Exits

A. Means of egress in the parking structure shall be arranged such that travel distance shall not exceed 300 feet for open floors of nonsprinklered, open parking structure, in accordance with IBC, Section 1016.1.

B. The travel distance to an exit shall be measured on the floor or other walking surface as follows:

1. Along the centerline of the natural path of travel, starting from the most remote point
2. Curving around any corners or obstructions, with a 12-inch (305-mm) clearance there from
3. Terminating at one of the following:
    a. Center of the doorway
    b. Other point at which the exit begins
    c. Closest riser of open stairs

23.10.6 Stairways

A. Stairways in the open parking structure that serve only the parking structure shall not be required to be enclosed. Such stairways shall be permitted to egress through the open parking garage at the level of exit discharge.

B. Areas of refuge: Areas of refuge shall not be required at exit stairways serving the open parking garage.

23.10.7 Means of Egress Illumination

Means of egress shall be illuminated in accordance with IBC, Section 1006, or with natural lighting that provides the required level of illumination in structures occupied only during daylight hours.

23.10.8 Emergency Lighting

Parking structure shall be provided with emergency lighting in accordance with IBC, Subsection 1006.3.

23.10.9 Marking of Means of Egress

Means of egress shall have signs in accordance with IBC, Section 1011.

23.10.10 Fire Protection

A. Sprinkler system and fire alarm system: automatic sprinkler and fire alarm systems shall not be required in spaces or areas of the open parking structure.

B. Standpipe System: a Class I manual standpipe system shall be installed throughout the open parking structure where the highest floor is located less than 150 feet above the lowest level of fire department vehicle access. A Class III standpipe system shall be installed throughout the open parking structure where the highest floor is located more than 150 feet above the lowest level of fire department vehicle access.

C. The location of Class I standpipe hose connections shall be in accordance with IBC Subsection 905.4. The Class III standpipe hose connections shall be in accordance with IBC Subsection 905.6.

23.10.11 Ventilation

A mechanical ventilation system shall not be required in the open parking structure.

END OF CHAPTER